Improving Odometer Reliability at Stewart-Warner Corporation (A)

The odometer is an essential part of automotive instrumentation. With recent extensions of warranty periods in the automotive industry, odometer reliability has become more and more important. The device itself is really a gear train with gears (wheels) stacked adjacent to one another driven by internally placed transfer pinions. With current usage in the millions, the problem of improving reliability must be considered in terms of minimizing application restrictions and manufacturing costs.

This case was prepared by Professor H.T. Gencsoy of West Virginia University, during the 1967 Summer Institute on Case Methods supported by the National Science Foundation at the University of Illinois. The assistance of Myron T. Johnson, Chief Engineer of the Instrument Division, Stewart-Warner Corporation, Chicago, Illinois, is gratefully acknowledged.

The odometer is an essential part of automotive instrumentation. (Refer to Exhibit A-1 for a view of the speedometer assembly showing the odometer in place.) The device itself is really a gear train with gears (wheels) stacked adjacent to one another driven by internally placed transfer pinions. (An odometer assembly drawing is shown in Exhibit A-2.) The tenth dial of the odometer is also a gear which imparts motion to the system. This gear in turn is driven from the main drive of the speedometer assembly through a double reduction worm gear system. With current usage in the millions, the problem of improving the reliability of the system must be considered in terms of minimizing application restrictions and manufacturing costs.

Stewart-Warner Corporation of Chicago, Illinois, is one of the major manufacturers of odometers. In its Chicago plant the company produces about 16,000 odometers a day and sells them to its customers, either separately or as parts of complete speedometer assembly packages. Among its customers are some of the major automobile companies (Chrysler, American Motors, Ford), as well as marine and agricultural equipment manufacturing companies. In 1966 net sales of Stewart-Warner Corporation were $171,325,315.00, including total sales from all its divisions and subsidiaries.

The Problem: How to Make the Odometers More Reliable

Mr. Myron Johnson, chief engineer of the Instrument Division, explained the problem. "Odometers are high volume, low cost items. We sell them for about 30 to 40 cents apiece. And yet our customers insist on high reliability of this product with constant improvement of its components." The reason for this high reliability specification by the users was understandable. Odometers record the age of a vehicle. Since the manufacturers now provide more extensive warranty conditions with their product, they must depend greatly on the accuracy and reliability of the odometers they install in their vehicles. Through the introduction of modern data processing techniques, practically all companies are keeping better records of the failures or malfunctions of their products and parts. This in the long run gives them an idea about the real cost of their warranty. It also helps them make better reliability studies, resulting in improved

product qualities. To do this properly, they must know exactly when a particular failure occurred in the life of the vehicle. And they can only tell this from the odometer readings.

Failure of an odometer to function properly during the warranty period may cause vehicle manufacturers two types of expense. One is the direct cost of replacing the failed odometer. Since labor costs would prohibit replacing only the defective odometer from the speedometer assembly, the custom is to replace the whole speedometer assembly. This is also expensive, since the complete instrument panel must be removed from the vehicle to install the new speedometer assembly. Average cost to the companies of this procedure is about $15.00 per vehicle. Mr. Johnson added, "To replace a 35 cent item, it will cost the companies $15.00. In the meantime you have an irritated customer who may decide to change his allegiance to other products after going through all the service difficulties and inadequacies of some authorized dealers. Thus this little incident may cost the company some of its future sales."

The other direct cost of a defective odometer to the manufacturer of the vehicle may be more involved. A major component (such as transmission, differential or engine, etc.) may actually fail after the warranty period (mileage), yet the customer may insist that according to his (incorrect) odometer reading he is entitled to full compensation. Mr. Johnson summarized the problem by saying that the basic problem was to provide an improved product without major retooling.

To do this Stewart-Warner Corporation had to re-evaluate the reliability criteria. "For most products," said Mr. Johnson, "if you have a reliability value of 99%, this is considered good. But in our case, this is not enough. Suppose that we sell 1,000,000 of these odometers to a customer. If 1% fails, that means 10,000 replacement jobs. And that will cost the company $150,000.00 to correct it. The companies require 100% reliability. But a more realistic value is in the range of 99.9%."

An average odometer assembly is made of four odometer dials, one odometer shaft, two collars, one gear and tenth dial, and four pinion and bracket assemblies, and all

of them in series with each other. (Refer to Exhibit A-2.) Since the reliability of a series system is equal to the product of the reliability of each component, that meant a reliability value higher than 99.9% for each component making the assembly.

Stewart-Warner Corporation had run some reliability tests on the odometers in their laboratories in the Instrument Division. This was a life cycle test in an environmental chamber at varying speeds and temperatures with no real statistical reliability analysis attached to it. Test results were found to be inconclusive and not representative of field failures. Mr. Thomas McCook, Assistant Director of Engineering at Alemite and Instrument Division, stated his company's decision to rely on field reports by saying, "You cannot effectively substitute laboratory tests for field tests, although we all are trying at times."

For failure data Stewart-Warner Corporation depends on the information obtained from the car manufacturers. Each defective odometer is sent back to the company by the car manufacturer, complete with its speedometer assembly, failure date and cause of complaint. Stewart-Warner then examines the end play of the odometer, tests it for functional requirements, and lists its findings with recommended design corrections. In this analysis the party responsible for the cause of failure (Stewart-Warner or the car manufacturer) is also identified. The car manufacturer is informed of this decision and corrective action is taken. For greater detail a sample of an odometer analysis list compiled by Stewart-Warner is shown in Exhibit A-3.

This procedure enables Stewart-Warner Corporation to obtain complete field feedback information and to study certain characteristics of failed parts. By looking for reasons and patterns of failure, the company can pinpoint with great accuracy the appropriate areas for possible design changes and improvements.

Odometer Components and their Functions

The major part of an odometer consists of four (or more) pinion and carrier assemblies, each one sandwiched between two consecutive dial wheels, all mounted on a steel shaft

with collars. The shaft and carriers are located in a frame. Refer to Exhibit A-2 for greater detail. Pinion and carrier assemblies transfer the motion from one dial wheel to the other in the ratio of 10 to 1. The motion is imparted in the following manner: the external spur gear of the tenth dial and gear (odometer dial, dummy) is driven from the main shaft of the speedometer main drive through a double reduction worm drive. This wheel has two internal teeth in contact with one side of the pinion on the carrier assembly. The other side of this pinion is in contact with the unity dial wheel which has twenty internal teeth. When the tenth dial makes one complete revolution, the pinion is rotated by the two internal teeth. This motion is then imparted to the unity wheel which also rotates two teeth. Hence the displacement ratio from one wheel to the other is 2/20 = 1/10. The motion is carried in the same manner all the way to the farthest left dial, always in the ratio of 10 to 1 at each step, through a pinion and carrier assembly. For greater detail, refer to Exhibit A-4 for odometer dial-dummy with the external spur gear, to Exhibit A-5 for odometer dial wheel, to Exhibit A-6 for pinion and bracket assembly, to Exhibit A-7 for the large pinion bracket, to Exhibit A-8 for the small pinion bracket, and to Exhibit A-9 for detail of the brass pinion. Exhibit A-10 is a photograph of the pinion and carrier assembly and the separate view of each part.

The brass pinions and the plastic pinions all have six teeth on one side and three full teeth on the other side along with three recessed teeth. In the assembly, the recessed tooth rides on a shelf of the adjacent odometer wheel single tooth side, stabilizing the pinion. The shelf prevents the pinion from turning out of position before engagement into the single tooth. Thus the pinion position is not dependent upon the position of the next higher odometer wheel being stably maintained solely by friction of the mechanism. (Refer to Exhibit A-11 for an artist's sketch of the internal gear and pinion arrangement.)

"From all field reports of odometer failures," Mr. Johnson said, "one thing was getting very clear. In practically every case the proper contact between the brass pinion and the adjacent dial wheel was lost. We had specified a 0.003 to 0.007 inch end play for the whole odometer assembly (Refer to Exhibit A-2), and to secure this

we were using arbor presses with calibrated dial guages in the assembly line. However, we were still getting too many failures." Finally the major problem was traced to the inconsistency of the pinion and carrier assembly in the production. Dimensional variations in the final assembly were found to be the reason for many failures. These variations were occurring during the assembly of the brass pinion with the two side brackets while automatically projection welding them together. Too much pressure, when holding them together on the plates for welding, was changing the overall thickness of the pinion and carrier assembly. This was resulting in the wrong spacing of each component of the odometer, causing slips or binding wheel actions. During assembly on the automatic welding machine, plates holding the two pinion brackets would also shift slightly from time to time, resulting in misalignment of the pinion bearing holes. This would cause tightness and pinion motion binding in the final assembly. 100% inspection was becoming too costly for the company to do it continuously. The dial wheels were not causing any trouble. They were made by an injection molding process on automatic machines using polystyrene as wheel material. "Besides," said Mr. Johnson, "we had $100,000 invested in molds for these machines. To change them would be too costly. In the final analysis we had decided that our failures were caused by burrs still present in the assembled pinions, and by the inconsistency of the projection welding operation joining the two pinion brackets."

EXHIBITS ECL 71A

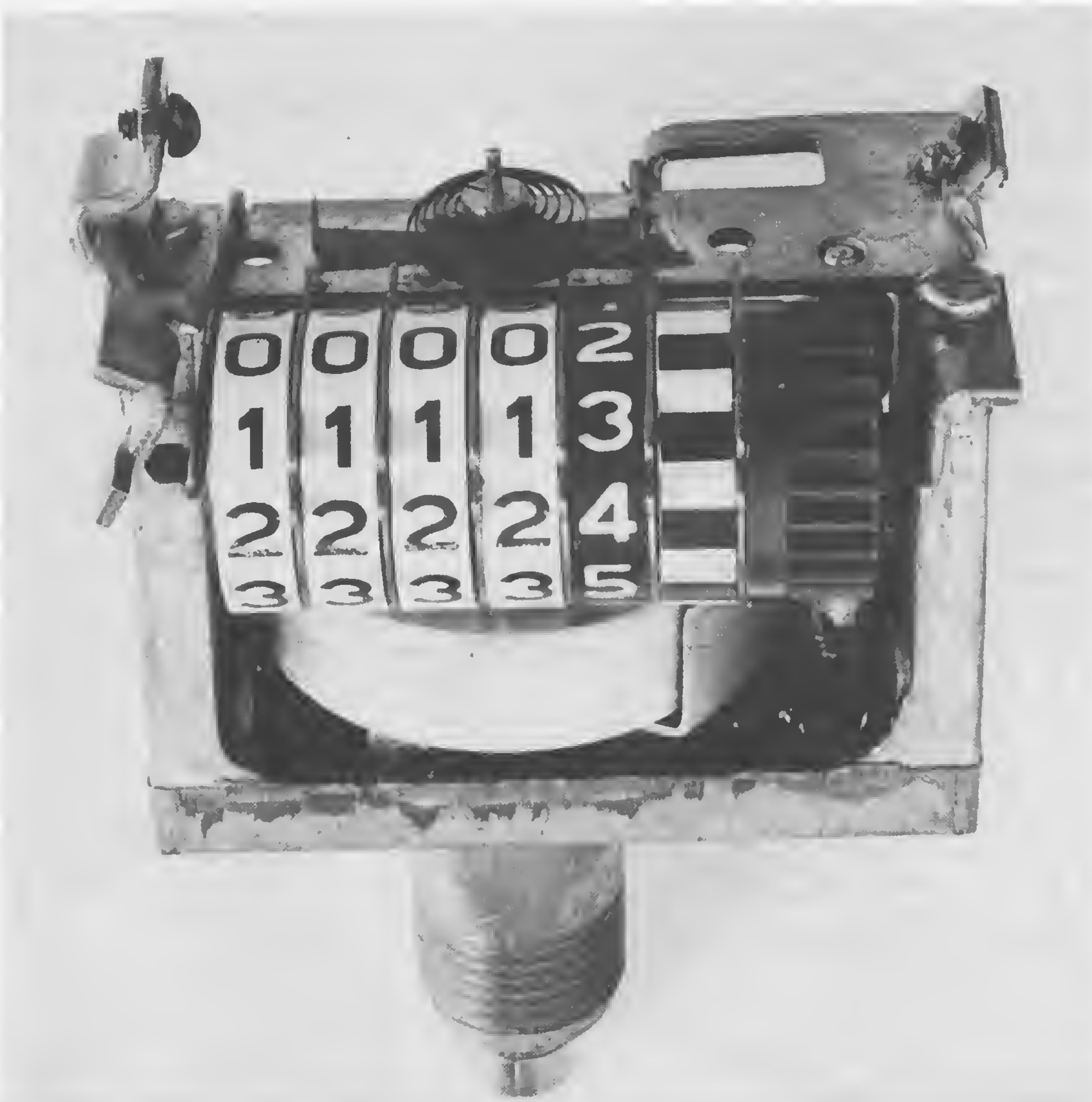


Exhibit A-1 SPEEDOMETER ASSEMBLY WITH ODOMETER IN PLACE

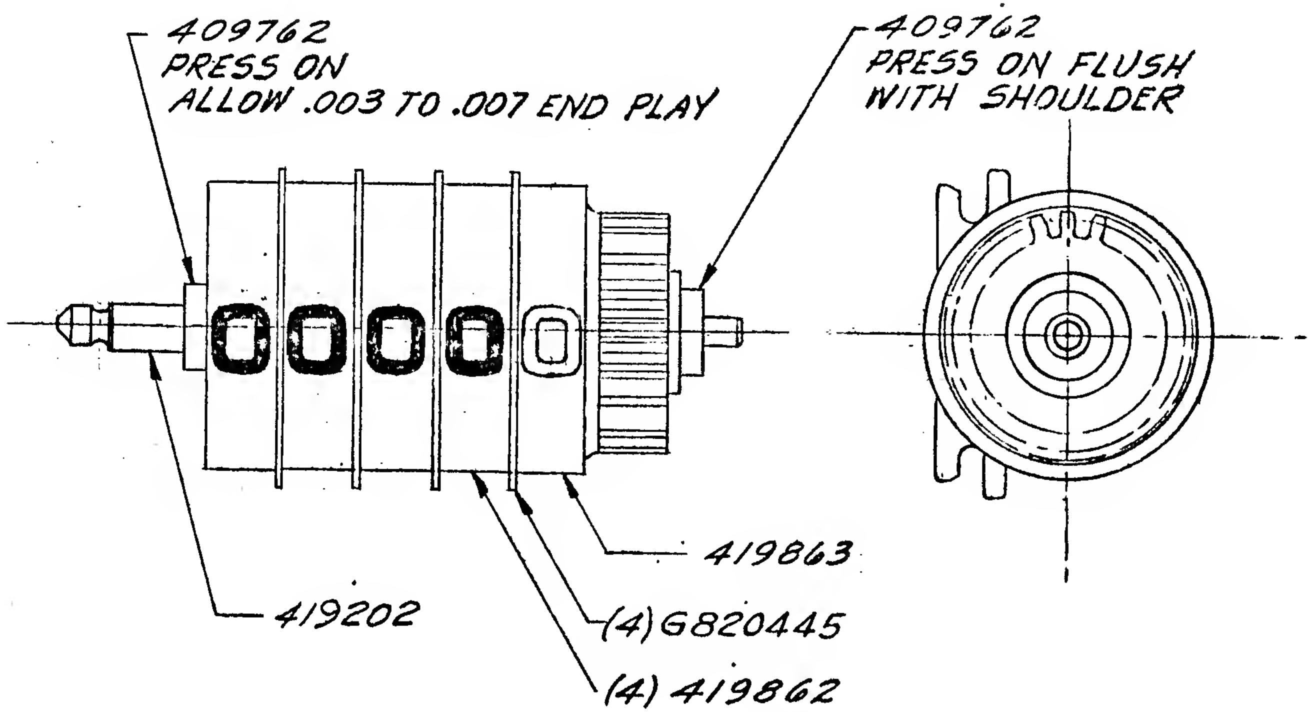


Exhibit A-2 ODOMETER ASSEMBLY DRAWING

NOTE -
LUBRICATE PER S.W. SPEC. PS9-1-106
ALL DIALS MUST RUN FREELY
AFTER ASSEMBLY.

G-419213

	REVISIONS	DATE	CHANGE NO.
A	409762 WAS 419205.	11-6-52	113595
B	419862 WAS 413403.	"	"
C	G-419863 WAS G-413402.	"	"
D	G-419863 OMITTED	4/26/55	121529
D,	419863 ADDED	4	"
E	G819669 WAS G415148	10/13/66	154028
F	G820445-1 WAS G819669	1-15-68	154994

REQ.	NUMBER	NAME
4	419862	DIAL, ODOM.
1	419202	SHAFT, ODOM.
2	409762	COLLAR
1	419863	10TH DIAL & GEAR.
4	G820445-1	PINION & BRACK'T.

D D, A B C A

NAME: ODOMETER ASSEM.

DRAWN BY	CHECKED BY	SCALE
PERLICK	Hirth	2:1

DATE OF DRW'G. 4-7-52
REL. FOR PROD. 5-6-52
APPROVED

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

DIMENSION VARIATIONS

DECIMALS ±.005, FRACTIONS ±.010, ANGULAR ±30', DRILLED HOLES S.W. STD. DB-1, PUNCHED HOLES S.W. STD. DB-2, STOCK SIZES AND MANUFACTURERS TOLERANCES NOT INCLUDED IN THE ABOVE. WHERE SHARP EDGES OR CORNERS ARE SPECIFIED .005 TO .008 RADIUS OR CHAMFER PERMISSIBLE.

√ INDICATES MAX. SURFACE ROUGHNESS IN MICROINCHES TO BE FREE FROM BURRS. ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.

USED ON G-419216
EX-28696-L

ECL 71A

G-419213

Part No.	S-W No.	Cust. No.	Carline	Failure Type	Failure Date	Date of Mfg.	Tag Ident.	Miles	Complaint
1	676AA	C7SF-17A265-B	A	Field	10/66	7-25-66	KXB1443 Perkins Mtrs. Fayette-ville, N.C.	90	"Sticks"
2	428981	COAF-17A265-B	B	Field	10/14/66	6-8-66	61727	27.9	"Odometer does not work"
3	676AA	C7SF-17A265-B	A	Field	10/66	8-16-66	LXR1821 Thompson Auto Mattoon, Ill.	1.9	"Sticks"
4	428981	COAF-17A265-B	B	Field	10/25/66	7-6-66	47167 Doenges Mtrs. Tulsa, Okla.	51.3	"Noisy be shaft"
5	428981	COAF-17A265-B	B	Field	10/26/66	6-21-66	4231F Parkway Ford Dickinson, No. Dak.	699.9	"No trip mileage"
6	676S	C7SF-17A265-F	C	Field	10/25/66	7-27-66	20516 Boro Mtrs. Metuchen, N. J.	29.9	"Seized"

Exhibit A-3 S-W ODOMETER FAILURE ANALYSIS LIST

RPORATION

CEIVED 12/7/66

End-Play (.003-.007)	Functional Test	Findings	Responsibility	Design	Correction
.005	Failed	Bad journal weld causing misset.	S.W.	Brass pinions	Weld made on old assembly machine. Sampled every hour and audited twice daily. Plastic journal plates will eliminate this problem
.0025	Failed	Bent journal - damaged. Hub cracked chip in teeth of mile dial. Hole in journal plate undersize.	S.W.	Brass pinions	The undersize journal hole caused binding and subsequent failure. This undersize condition is caused by shifted plates. These parts are sampled every hour on the machine to assure hole size.
.0055	Failed	Misset tenth dial. Plastic dial lock-ing ring damaged by long tooth of pinion.	S.W.	Brass pinions	We have three (3) positions. Were missets, should be rejected. Assemblies, exercises and visual inspection. All are 100% inspection operations.
.004	Passed	Same as #3.	S.W.	Brass pinions	Same as #3.
.004	Failed	Broken 100 mile dial. This unit was dropped and damaged in handling.	Ford	Brass pinions	None required.
-	-	Collar had been removed before received by S.W. Jaw marks on collar.	Ford	Brass pinions	None required.

STEWART-WARNER CO

ANALYSIS OF ODOMETERS R

Part No.	S-W No.	Cust. No.	Carline	Failure Type	Failure Date	Date of Mfg.	Tag Ident.	Miles	Complaint
7	676AA	C7SF-17A265-B	H	Field	10/66	8-18-66	KXB1196 Gerald Mtrs. Skokie, Ill.	2.1	"Inopera-tive"
8	676AA	C7SF-17A265-B	H	Field	9/66	8-11-66	KWT0449 B.Borst L-M,Inc. Birming-ham, Mich.	19.9	"Inopera-tive"

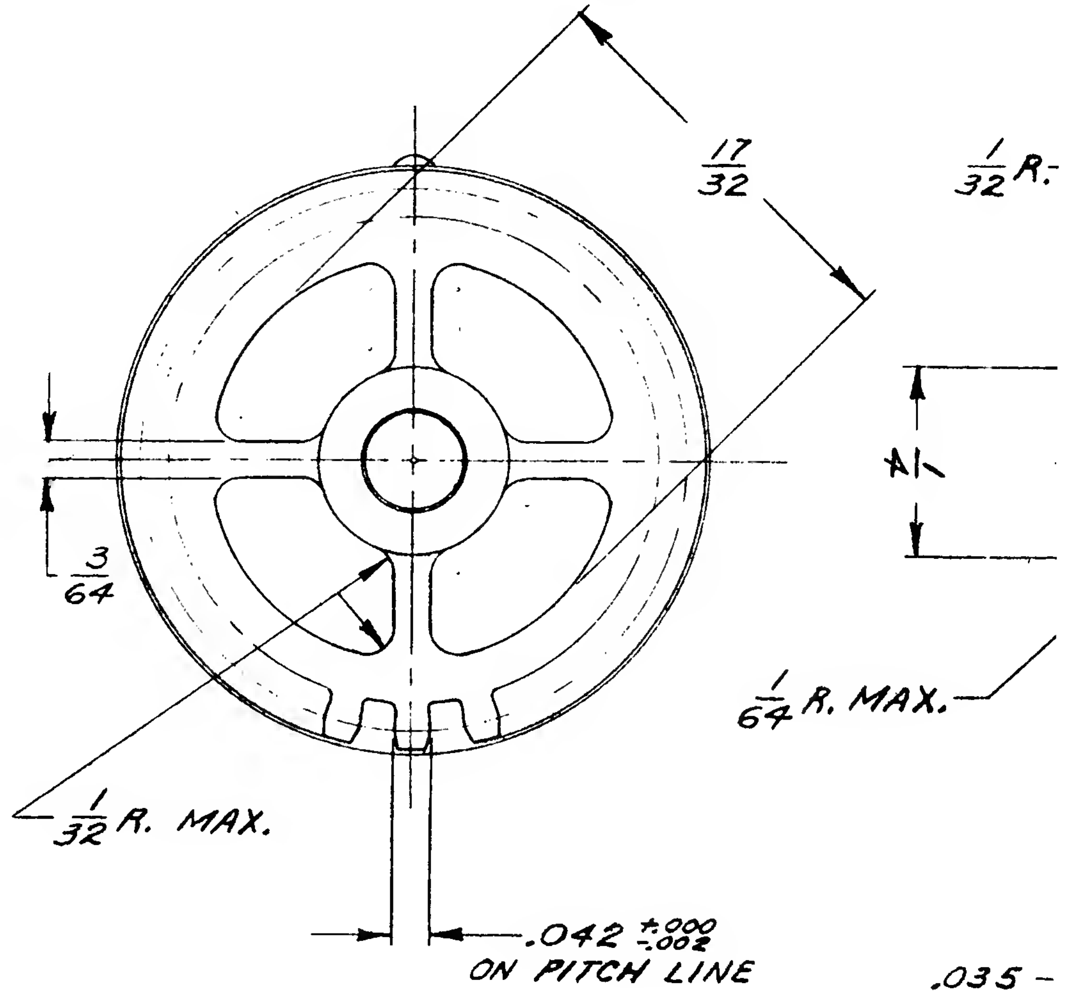
Exhibit A-3 S-W ODOMETER FAILURE ANALYSIS LIST

ORATION

EIVED 12/7/66

End-Play (.003-.007)	Functional Test	Findings	Responsibility	Design	Correction
.0045	Failed	Broken tooth in 10 mile dial.	S.W.	Brass pinions	We could find no reason for failure other than possible damage through handling.
.0045	Failed	Burr on pinion 2nd plate.	S.W.	Brass pinions	Tooth of pinion appeared to be damaged as area was bright. We are sampling these parts to 1% level. Plastic pinions should correct this problem.

TEETH	25	
PITCH	34	
O.D.	.775 $^{+.000}_{-.003}$	UNDERSIZE
P.D.	.716 $^{+.000}_{-.003}$	UNDERSIZE
R.D.	.6416 $^{+.000}_{-.003}$	UNDERSIZE
DEPTH	.0667	
P.A.	20° WITH TIP RELIEF (SEE ENLARGED VIEW)	



OTHERWISE SAME AS 409764.
SIMILAR TO 429178.

LOCATION OF TEETH IN SPUR GEAR TO TOOTH SPACE ON DIAL NOT IMPORTANT.

DRAWN	DATE	NAME
W.J.P.	12-21-59	DIAL, ODOM. - DUMMY.
CHECKED	SCALE	FINISH
	4:1	
		HEAT TREATMENT
		MATERIAL

REQ.	NUMBER	NAME

UNLESS SPECIFIED, DECIMALS ± .005 FRACTIONS ± .010, ANGLES ± ½°
SHARP FILLETS OR CORNERS. .005 MAX. RADIUS OR CHAMFER PERMISSIBLE
125 √ ON MACHINED SURFACES UNLESS OTHERWISE SPECIFIED
TO BE FREE OF BURRS.
ALL DIMENSIONS GIVEN IN INCHES
USED ON G-430304

STEWART-WARNER CORPORATION CHICAGO

LET.	REVISIONS	DATE	CHANGE NUMBER
A	"DUMMY" WAS "WITH SPUR GEAR"		
B	.042 MAX. X .04 WIDE N/B ADDED		
C	SEE 409764	4-5-67	
D	SEE 409764	3/68	15567

EX-430303

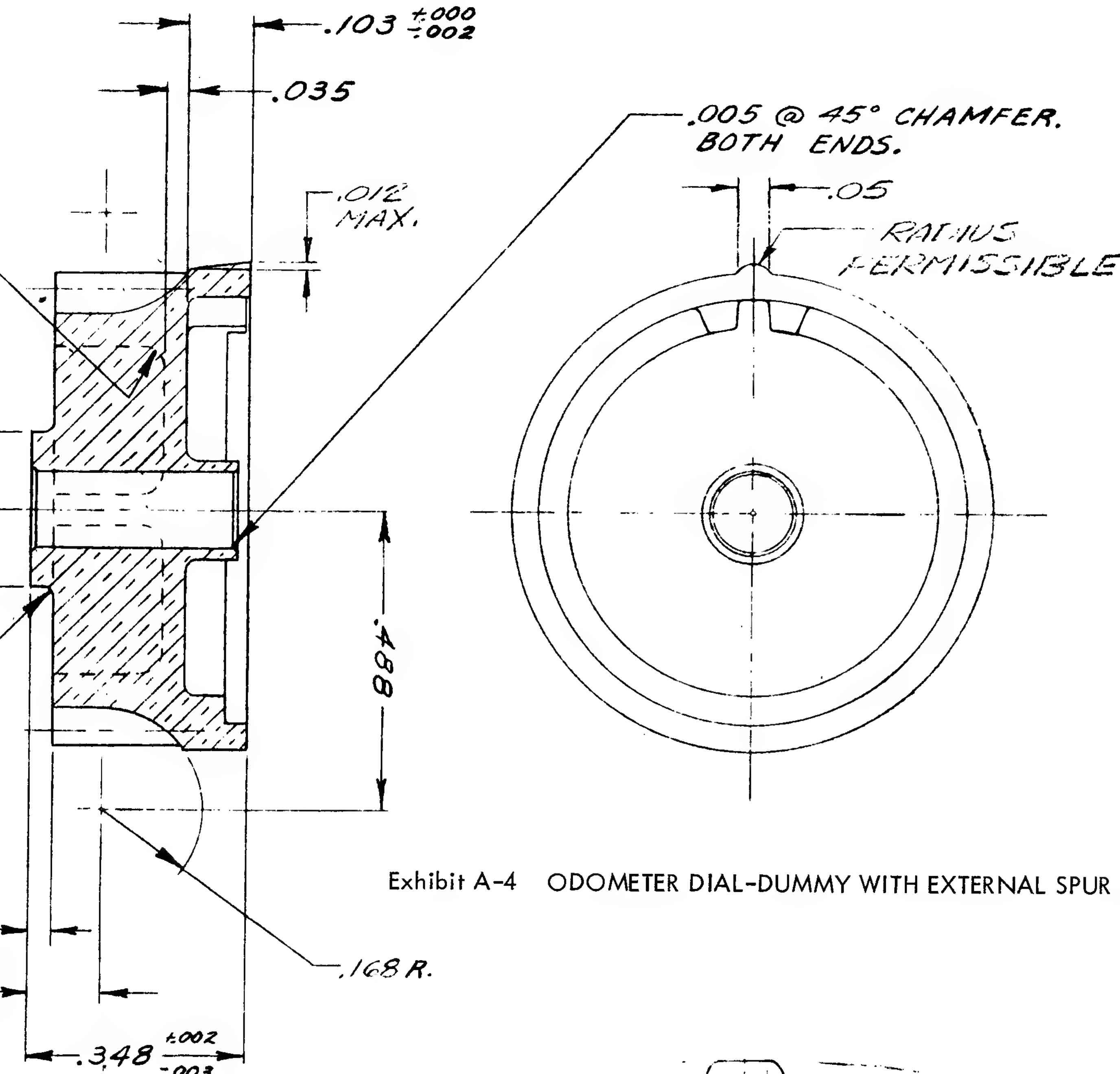
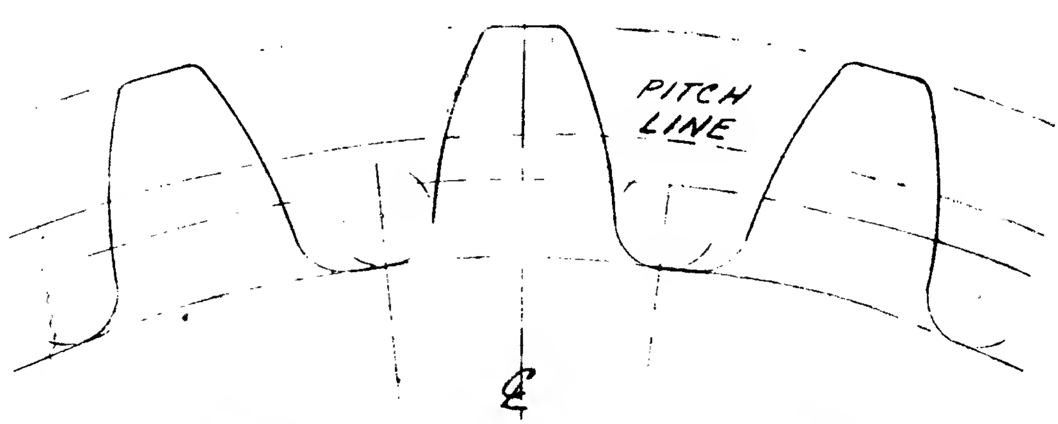


Exhibit A-4 ODOMETER DIAL-DUMMY WITH EXTERNAL SPUR GEAR



ENLARGED VIEW OF SPUR GEAR
SCALE: 20:1

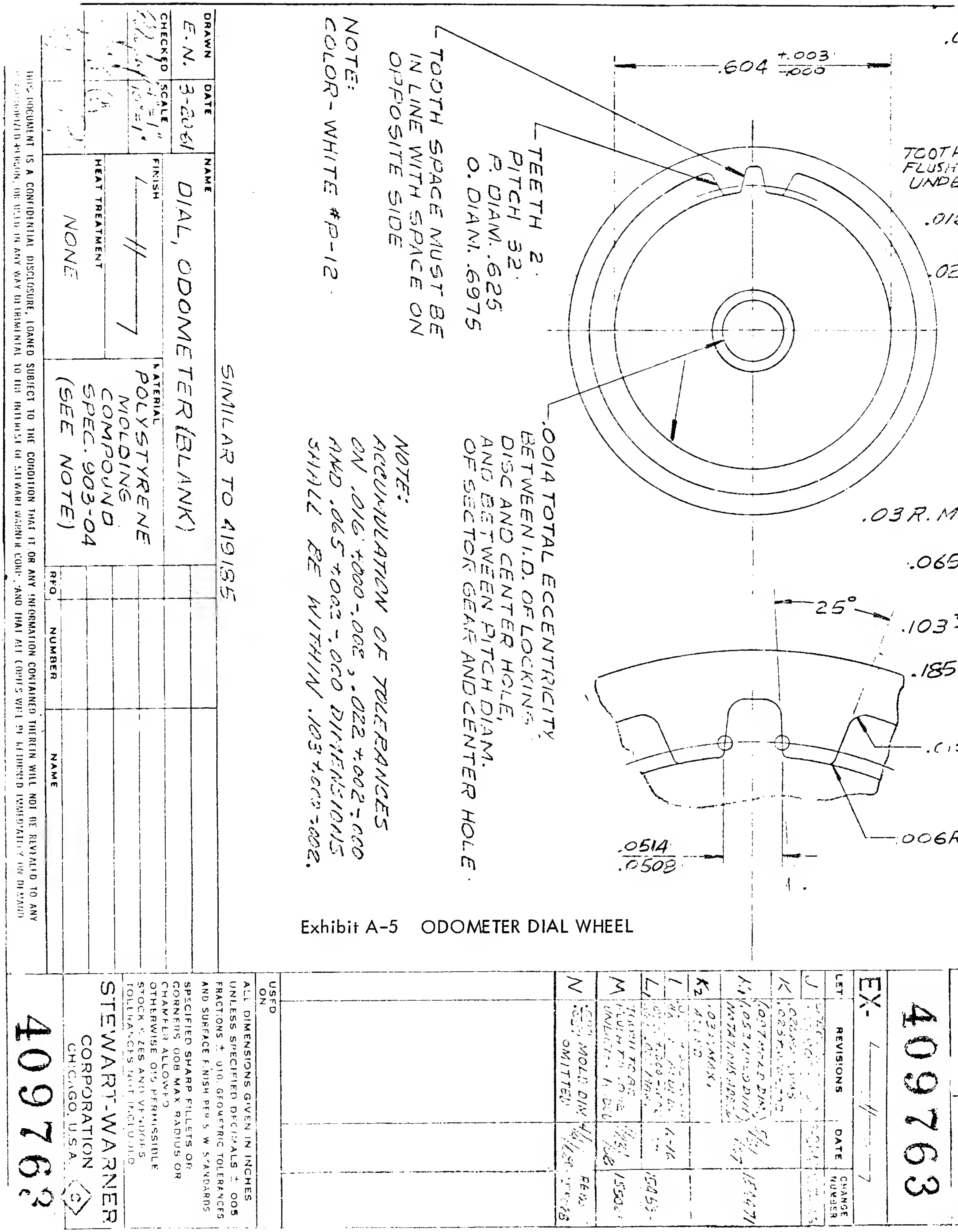
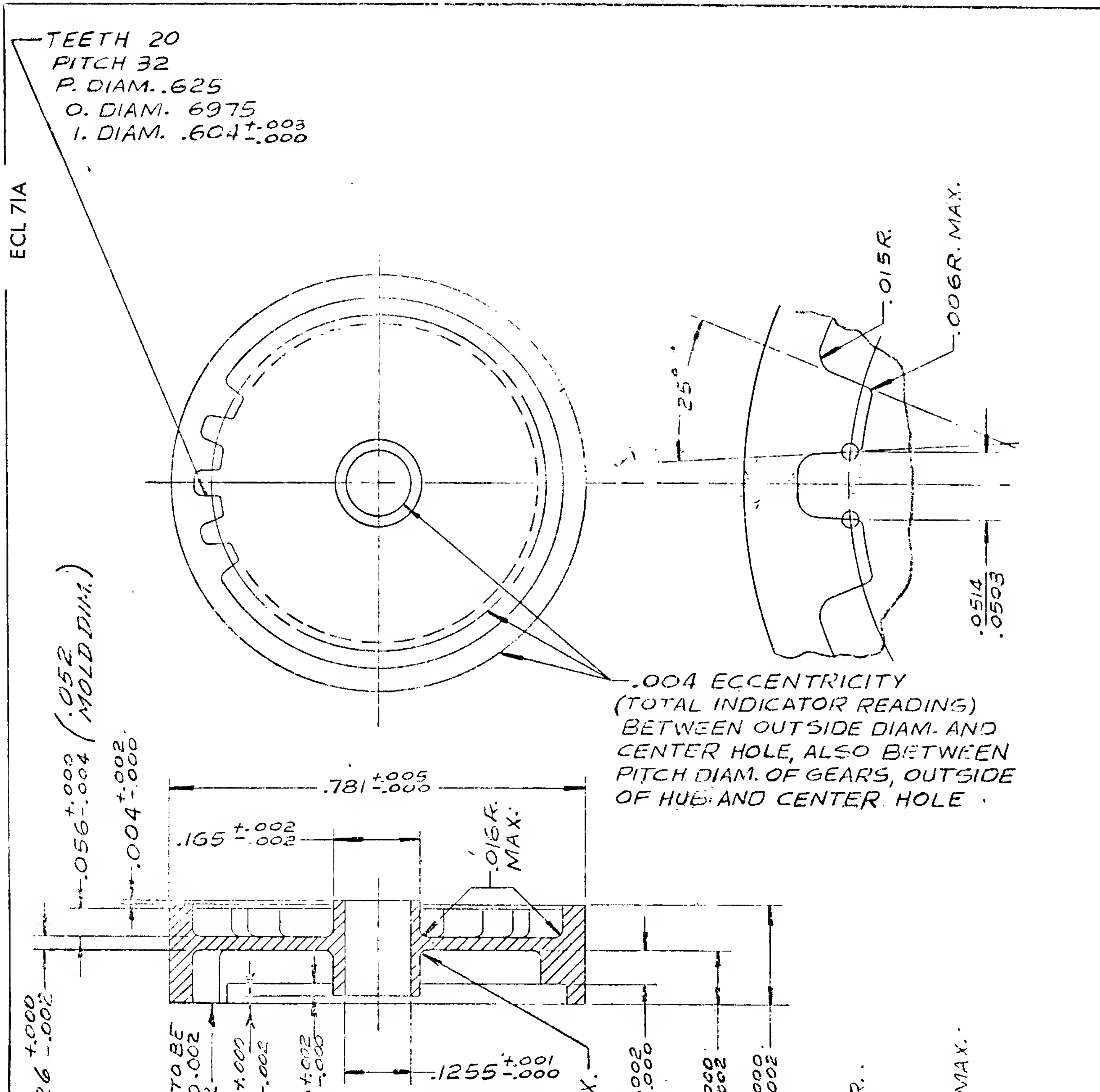


Exhibit A-5 ODOMETER DIAL WHEEL

ECL 71A



	428378
	427410
	426606
	~~[illegible]~~
821513	426079
428850	424301
820235	~~[illegible]~~
819579	424038
818624	424031
818650	423228
818244	~~[illegible]~~
816520	422333
816335	419967
814504	419966
816619	419862
814853	~~[illegible]~~
~~814304~~	418527
~~[illegible]~~	~~418485~~
811118	418470
810944	~~[illegible]~~
~~[illegible]~~	~~418435~~
~~[illegible]~~	418354
431003	417352
432320	~~[illegible]~~
430843	416685
430340	416406
430476	~~[illegible]~~
430126	~~[illegible]~~
429213	~~415430~~
428711	~~[illegible]~~
428674	413403
428641	409765

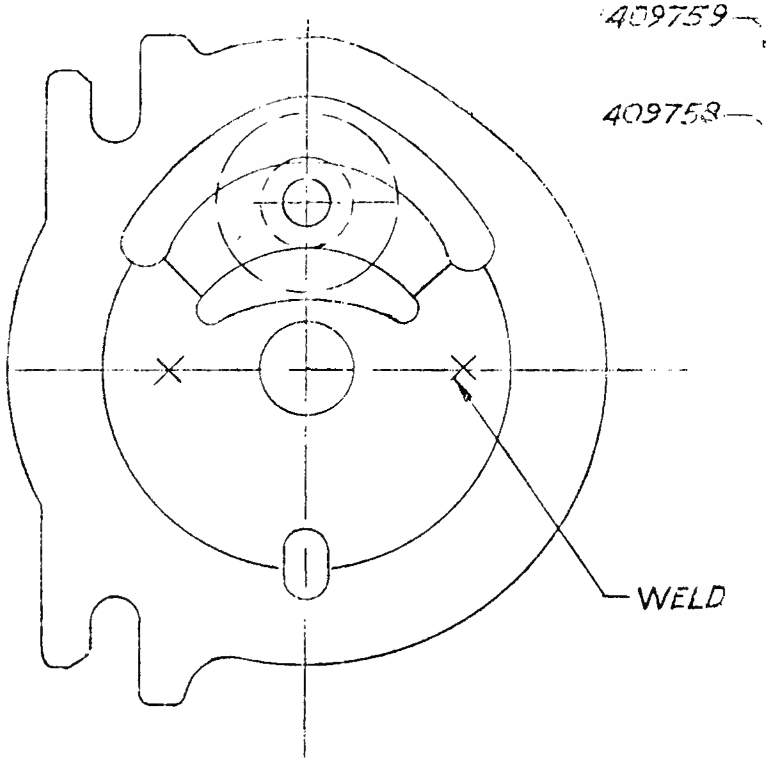


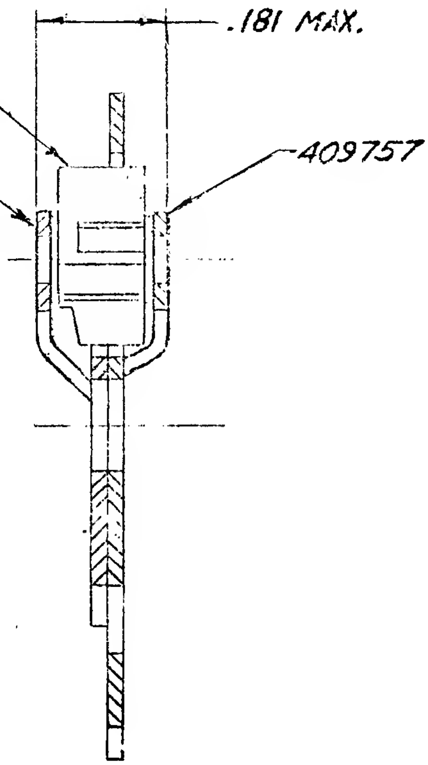
Exhibit A-6 PINIO

NOTE:
PINION MUST TURN FREELY AFTER ASSEMBLING & MUST BE ASSEMBLED IN RELATION TO BRACKET AS SHOWN.
REFER TO PS9-1-106 FOR LUBRICATION REQUIREMENTS.

ORVILLE JOHNSON	4-8-58	PINION & BRACKET ASSEM.
	4=1	

1	4
1	40
1	40
REQ	

ECL 71A



AND BRACKET ASSEMBLY

G-409767

EX 25783-AC

LET.	REVISIONS	DATE	CHANGE NUMBER
B	LUBRICATION WAS DIDN NOT VASELINE	4-8-58	124542

G-814852
G-812864
G-416003
REFER TO

FIRST USED ON

ALL DIMENSIONS GIVEN IN INCHES.
UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01.
SURFACE FINISH PER S.W. STANDARDS.
SPECIFIED SHARP FILLETS OR CORNERS .005 MAX. RADIUS OR CHAMFER ALLOWED.
OTHERWISE .015 MAX. PERMISSIBLE.
STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

9757	PINION BRACKET
758	PINION BRACKET
759	PINION
UMBER	NAME

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

G-409767

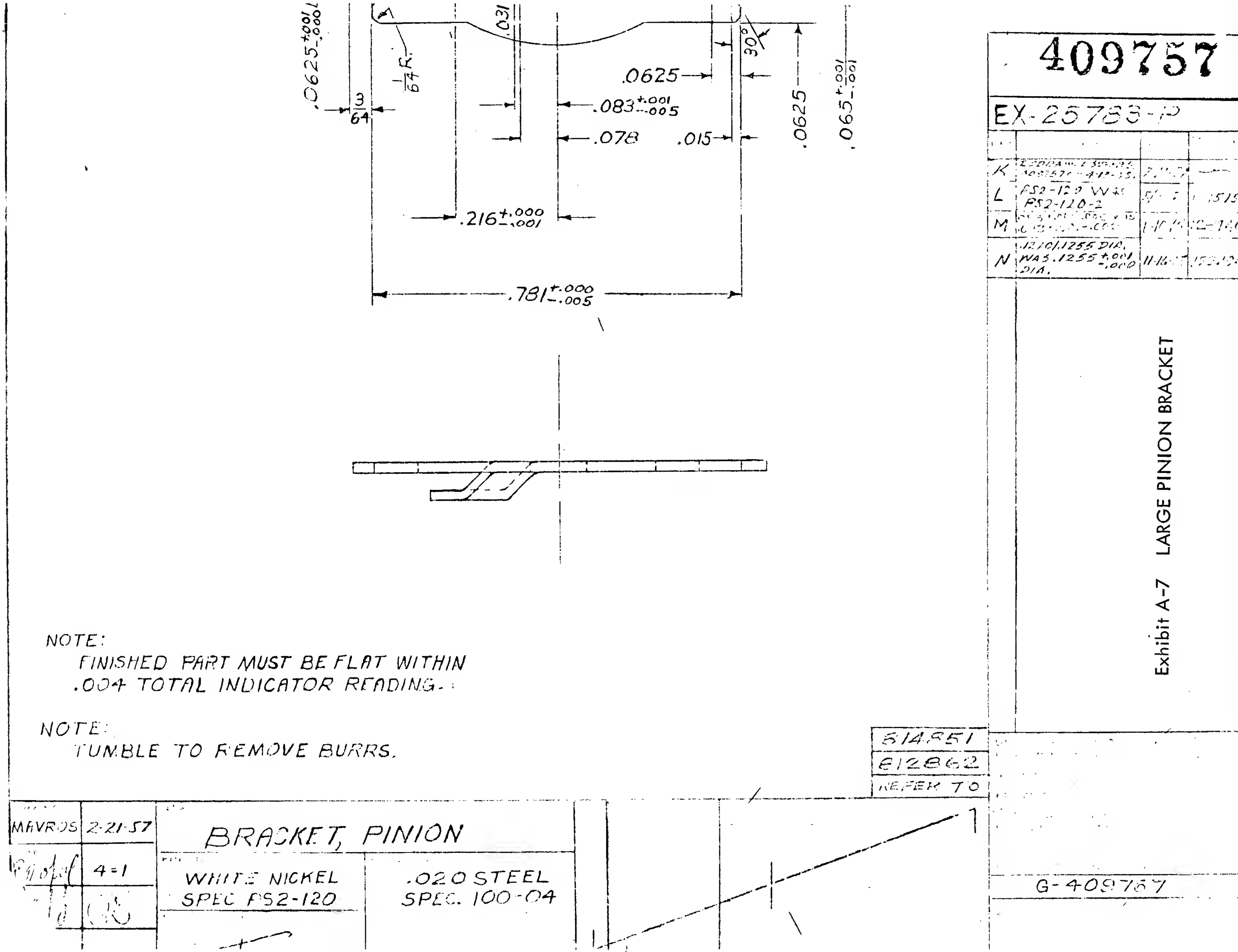
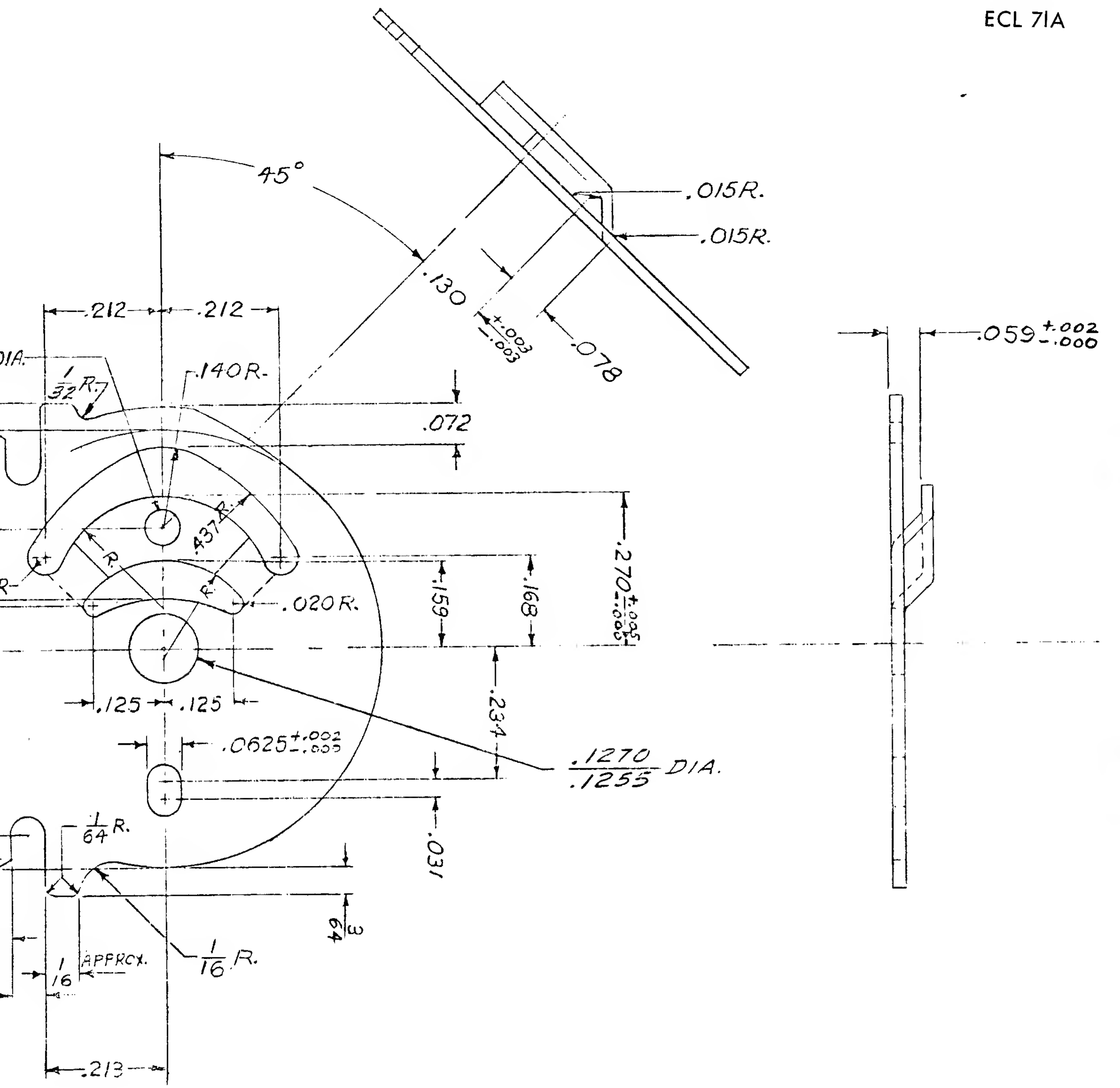


Exhibit A-7 LARGE PINION BRACKET


45°
.015R.
.015R.
.130
+.003
-.003
.078
.212
.212
DIA.
1/32 R.
.140R.
.072
.437R.
R.
R.
.020R.
.159
.168
.270 +.005 -.005
.059 +.002 -.000
.125
.125
.0625 +.002 -.000
.234
.1270
.1255
DIA.
1/64 R.
.031
3/64
1/16 R.
1/16
APPROX.
.213

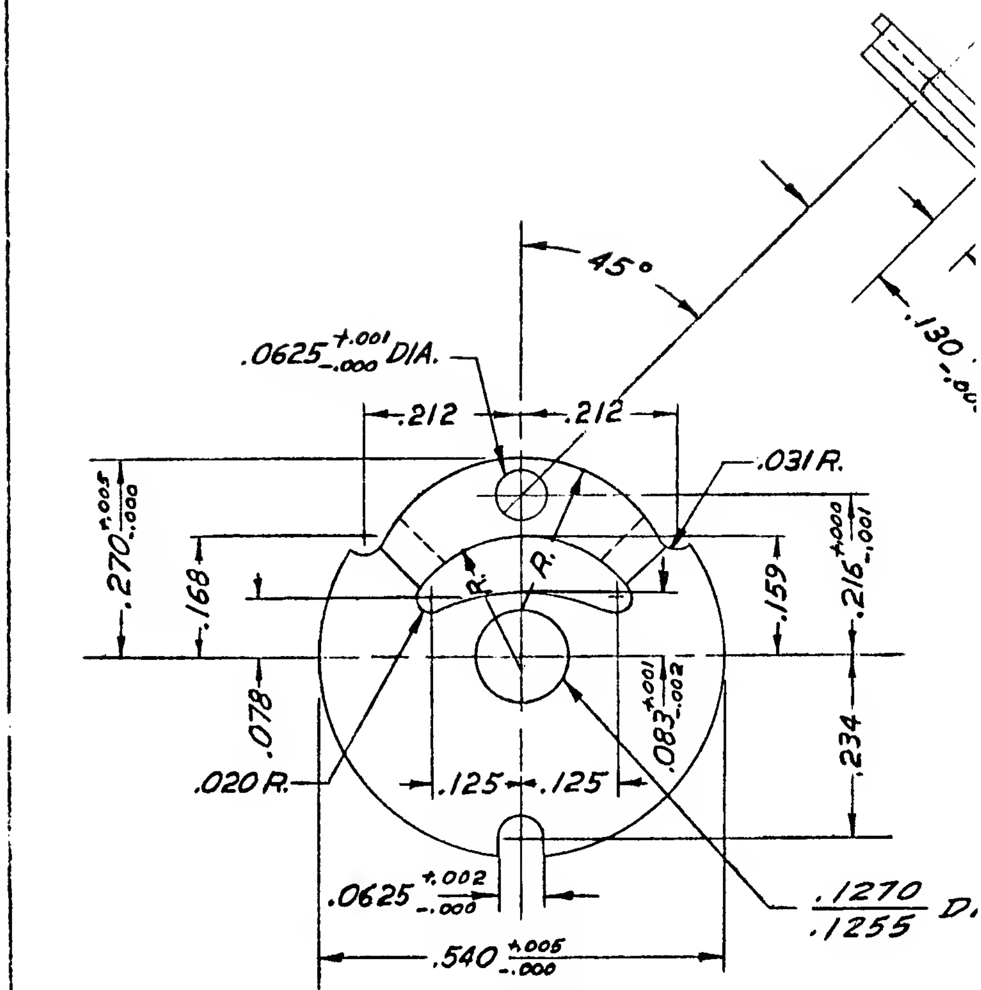


Exhibit A-8 S/

NOTE;
TUMBLE TO REMOVE BURRS.

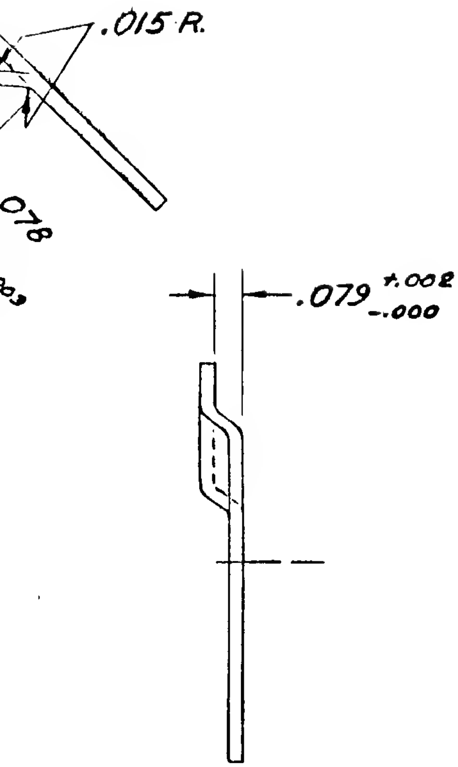
DRAWN	DATE	NAME	
ORVILLE JOHNSON	9-9-58	BRACKET, PINION	
CHECKED	SCALE	FINISH	MATERIAL
	4:1	WHITE NICKEL S.W. SPEC. #PS2-120	.020 STEEL SPEC. #100-04
		HEAT TREATMENT	
	1118	NONE	

ECL 71A

409758

EX 25703-Q

LET	REVISIONS	DATE	CHANGE NUMBER
F	P52-120 WAS P52-120-2.	5-3-57	123675
G	.1210/.1255 DIA, WAS .1255 $^{+.001}_{-.000}$ DIA.	11/16/65	153294



ALL PINION BRACKET

812863

REFER TO

NUMBER | NAME

USED ON G-409767

ALL DIMENSIONS GIVEN IN INCHES UNLESS SPECIFIED DECIMALS ± .005 FRACTIONS ± .010. GEOMETRIC TOLERANCES AND SURFACE FINISH PER S.W. STANDARDS.

SPECIFIED SHARP FILLETS OR CORNERS .005 MAX RADIUS OR CHAMFER ALLOWED OTHERWISE .015 PERMISSIBLE STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

409758

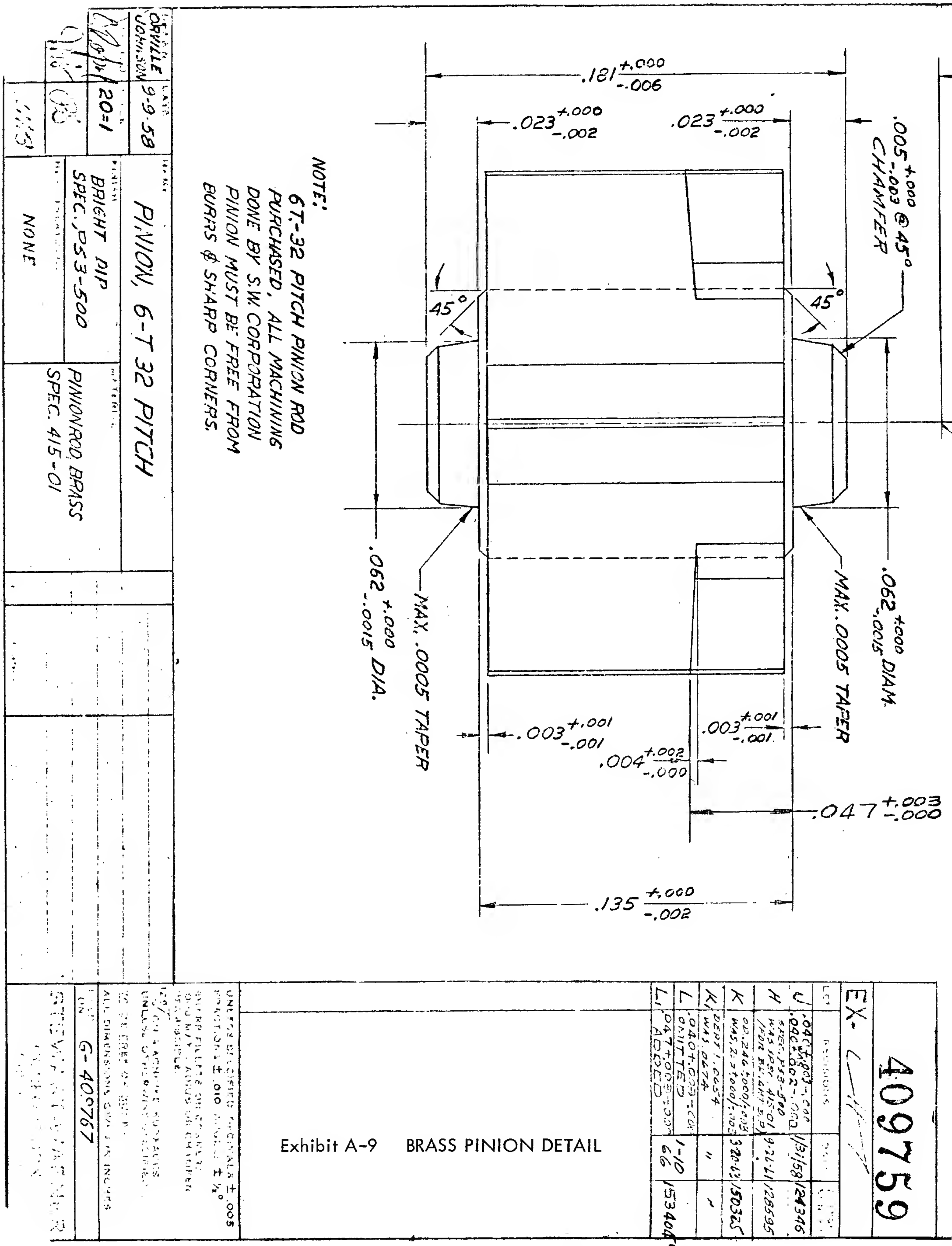
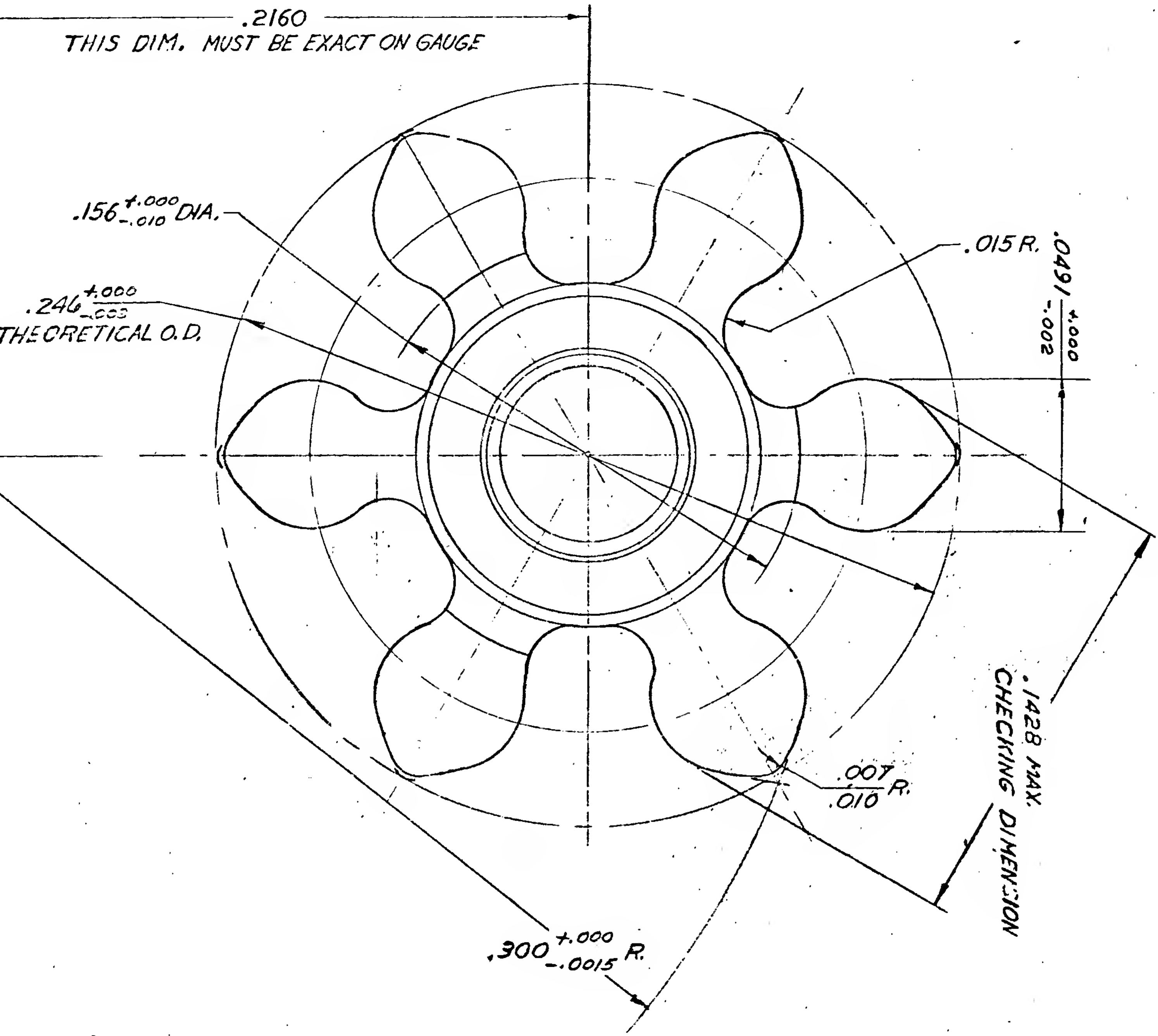


Exhibit A-9 BRASS PINION DETAIL



- TEETH 6
- PITCH 32
- O.D. .246 +.000 -.003
- P.D. .1875 +.000 -.003
- R.D. .1152 +.000 -.003
- DEPTH .0654
- PITCH DIAM. MUST BE CONCENTRIC WITH THE .062 DIAS. WITHIN .0015.

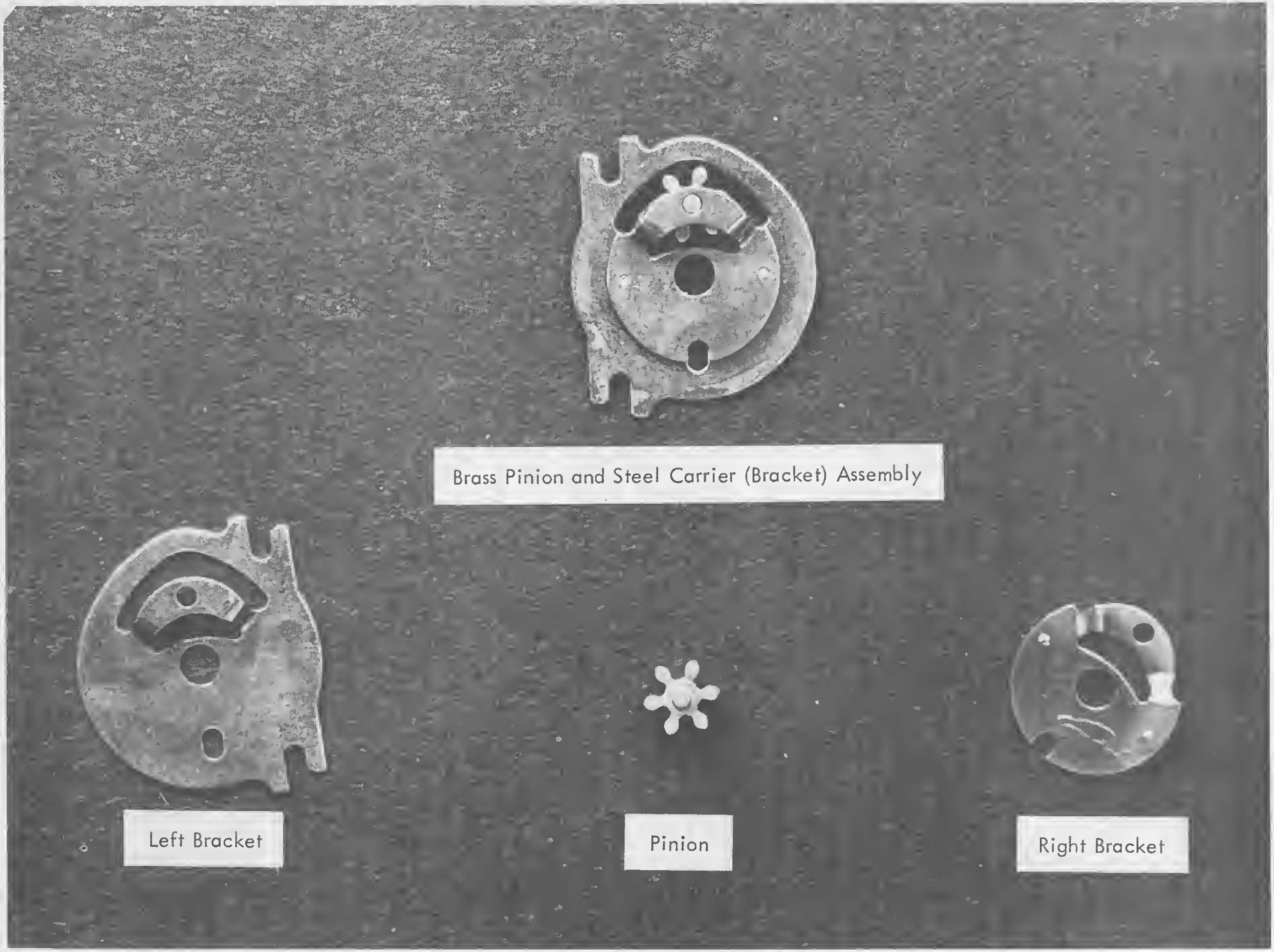


Exhibit A-10 PINION AND CARRIER ASSEMBLY

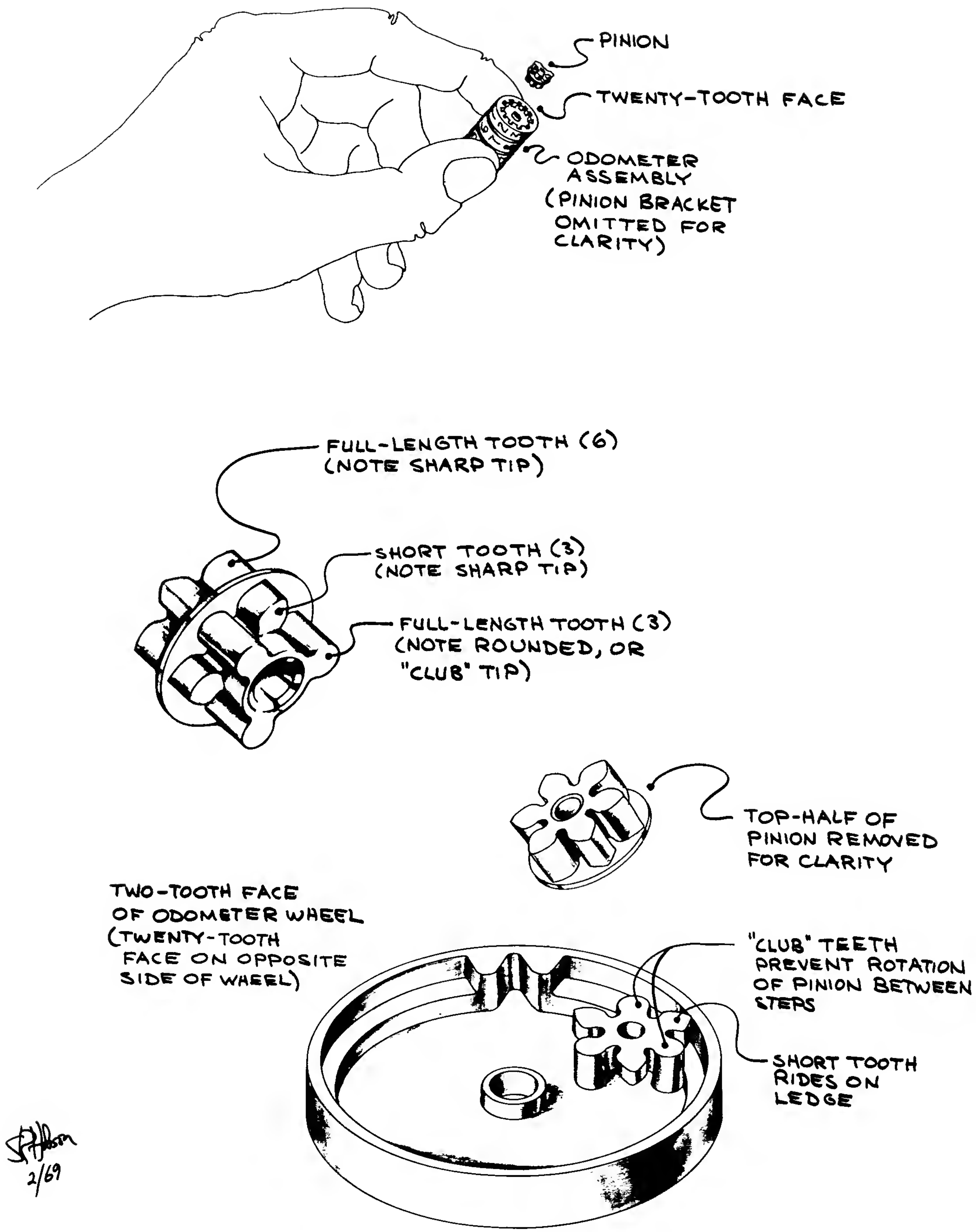


Exhibit A-11 SKETCH OF INTERNAL GEAR AND PINION ARRANGEMENT
(based on final design discussed in Part B)

Engineering Case Library

ECL 71B

Improving Odometer Reliability

at

Stewart-Warner Corporation (B)

Stewart-Warner Corporation continued to receive odometer failure reports from its customers. Finally the company was under too much pressure from users who were complaining of the unreasonable amount of money they were spending to remedy the defective odometers. "Problems always come slowly," said Mr. Johnson. "Customers are constantly inquiring for the reasons of failures and the improvements that we are contemplating. Finally, in 1963, we decided on change."

Mr. Patrick Powell was selected as Project Engineer to study this problem. An experienced draftsman, a model maker and a production engineer were assigned to work with him on the project. Mr. Powell had been with the company since 1952, starting as a draftsman. Since then he had attended night school at the Chicago Technical College and had obtained a B.S.M.E. in 1958. Recently he had been working as design engineer on various projects for the company.

Mr. Myron T. Johnson, Chief Engineer of the Instrument Division, had obtained a B.S. in Education in 1953, and a B.S. in Electrical Engineering in 1962, and currently was pursuing special studies under the Exectuive Program of the University of Chicago School of Business Administration for an M.B.A. degree.

This case was prepared by Projessor H.T. Gencsoy of West Virginia University, during the 1967 Summer Institute on Case Methods supported by the National Science Foundation at the University of Illinois. The assistance of Myron T. Johnson, Chief Engineer of the Instrument Division, Stewart-Warner Corporation, Chicago, Illinois, is gratefully acknowledged.

First Improved Design

Mr. Powell was well acquainted with the shortcomings of the present design. The unremoved burrs on the brass pinion and the dimensional variations due to the welding operation were causing most of the difficulties. The company policy was such that after a design was completed in the design department, it was the production department's job to manufacture it properly. The brass pinions were made at S-W's own plant on an automatic continuous screw machine. Parts were made of extruded stock and teeth were cut on an indexing head. For burr removal the parts were placed in a tumbling barrel containing a special compound of Number 95 liquid Ventrol. This process was the best that the Production Department could suggest for the removal of the burrs; nevertheless, it was not producing satisfactory results.

Mr. Powell had long been familiar with similar products marketed by S-W's competitors. He knew that some companies were using plastic pinions in such applications. Thus he first suggested replacing the brass pinion with a duplicate made of a poly-acetal resin compound (Delrin), retaining the rest of the original design unchanged. Upon the approval of this idea, the company decided to make some new test specimens. Molds for the new plastic pinions were ordered at a cost of $2,500. Twelve weeks later the first plastic pinions were ready for testing. Subsequent laboratory tests were found to be satisfactory and it seemed that the burr problem was now eliminated. Furthermore it was also noticed that since the plastic pinions had a smaller mass, the vibration characteristics of the new design was much better than the old one. Previously some odometers with brass pinions were known to have failed due to excessive vibration of the pinions under severe field conditions (tractors, heavy earth moving equipment, etc.). However, since the new assembly was still made on the same welding machine, the dimensional variations caused by the welding operations remained unsolved (see Exhibit B-7). By now a new problem resulting in defective parts had become apparent. Unless

all the parts were perfectly aligned during the welding assembly, plastic pinion bearings were easily sheared and partly damaged. This was producing excessive looseness of the pinion and hence causing it to lose contact with the internal teeth of the meshing dial wheels.

Second Improved Design

Mr. Powell knew then that he had to eliminate completely the welding operation. He decided to make a uniform, single piece part to replace the two brackets of the carrier unit. The functional requirements of the carrier were re-investigated and carefully scrutinized, and a new plastic pinion bracket and pinion were designed. Refer to Exhibit B-1 for the new pinion bracket, and Exhibit B-2 for the new plastic pinion, and Exhibit B-3 for pinion and bracket assembly. With this new design the vibration and the welding problems were completely solved, and the pinions were free of objectionable burrs. This design was immediately incorporated into the bicycle speedometer assembly. However, it soon became apparent that pinions could be dislocated from their proper positions by simply handling them during assembly operations. It was decided that this was undesirable for odometers that were sent to customers like Ford Motor Company for additional assembly into speedometers at their plant. This was attributed to the low rigidity and the excessive deflection of the short plastic shaft holding the pinion, and the poor locking characteristics of the new pinion in its seat.

Final Design

During various tests it was noticed that if the raised portion of the plastic pinion bracket was near the side where the 2-tooth wheel was located, it was impossible to dislocate the pinion from its correct position. Hence, a final design which was now completely satisfactory had become a reality. This was obtained mainly by rotating the plastic carrier 180° around its vertical axis from its original position. A new plastic pinion which had better locking capabilities was incorporated with this design. Locking flanges in the pinion bracket were increased to secure

the pinion more rigidly in place. Exhibit B-4 is for the new pinion bracket, Exhibit B-5 is for the new pinion,* and Exhibit B-6 is for the final pinion bracket assembly. Exhibit B-7 shows photographs of the pinion and bracket assembly through all the design stages and also the odometer plastic wheel which was unchanged.

As of July 1967, this final design was still not in full production. However, it was hoped that by November 1967, this would be completely available to the customers. "After that it will be approximately three months before we get the earliest field report," said Mr. Johnson, "and then we will know if we really solved all the problems."

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* Note that in the final design of the pinion, the non-recessed teeth on the side of the pinion which engages the single tooth side of the odometer wheel are shaped somewhat differently. These teeth have been shaved down in an effort to preclude any possibility of the tooth engaging the corner of the approaching single tooth of the adjacent odometer wheel, should the pinion be somewhat displaced because of a cocked shaft on which the pinion turns or because of some small imperfection such as a burr existing on the tooth form of the pinion or wheel.

EXHIBITS, ECL 71B

Exhibit B-1	Drawing, All Plastic Pinion Bracket.
Exhibit B-2	Drawing, Plastic Pinion (redesigned).
Exhibit B-3	Drawing, All Plastic Pinion & Bracket Assembly (intermediate design).
Exhibit B-4	Drawing, Final Design of Plastic Pinion Bracket.
Exhibit B-5	Drawing, Final Design of Plastic Pinion.
Exhibit B-6	Drawing, Final Design of Pinion & Bracket Assembly.
Exhibit B-7	Photograph, Pinion & Bracket Assembly Through Various Design Stages.

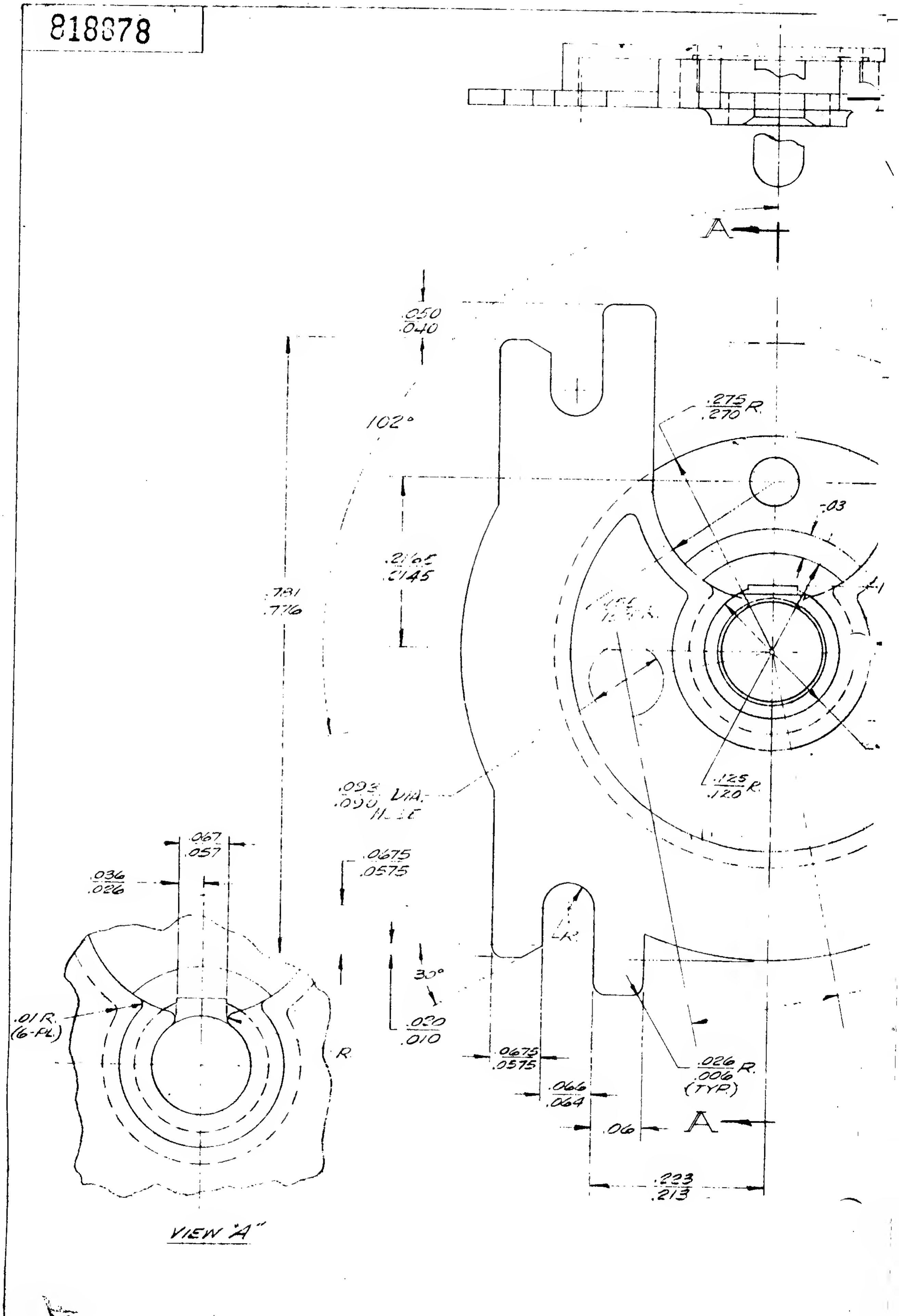
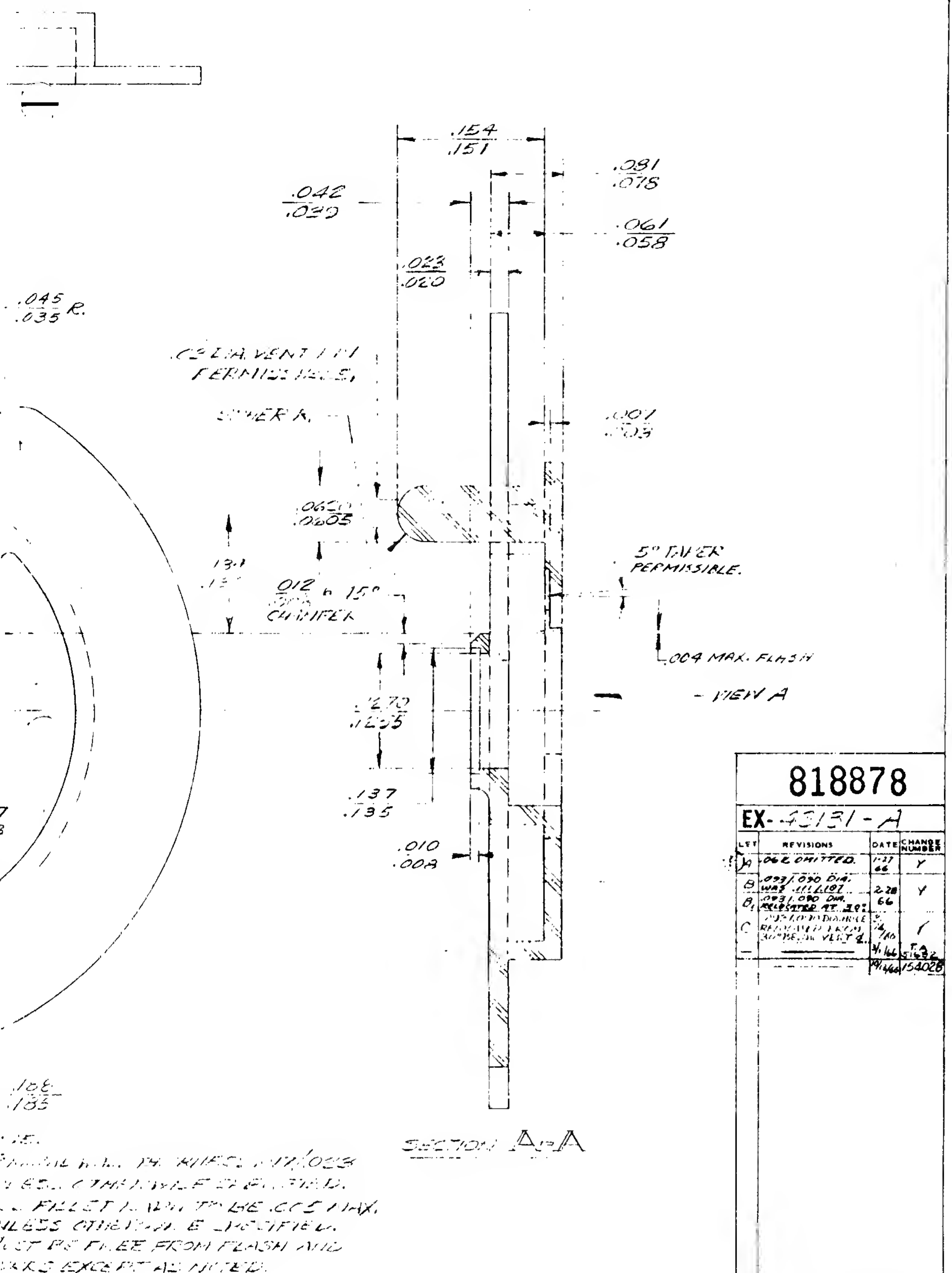


Exhibit B-1 ALL PLASTIC PINION BRACKET



818878
EX-43131-A

LTR	REVISIONS	DATE	CHANGE NUMBER
A	.062 OMITTED.	1-27-66	Y
B	.093/.090 DIA. WAS .111/.107	2-28-66	Y
B1	.093/.090 DIA. RELOCATED AT 30°		
C		4/66	
—		4/66	51682
		10/66	154028

FIRST USED ON G-81960

ALL DIMENSIONS GIVEN IN INCHES. UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01. SURFACE FINISH PER S.W. STANDARDS. SPECIFIED SHARP FILLETS OR CORNERS .005 MAX. RADIUS OR CHAMFER ALLOWED. OTHERWISE .015 MAX. PERMISSIBLE. STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

818878

DRAWN	DATE	NAME
R.	12-9-65	BRACKET, PINION
CHECKED	SCALE	
	2/1	

FINISH	MATERIAL
NONE	POLY-ACETAL RESIN MOLDING COMPOUND (DELRIN) 911-01
HEAT TREATMENT	
NONE	

REQ.	NUMBER	NAME

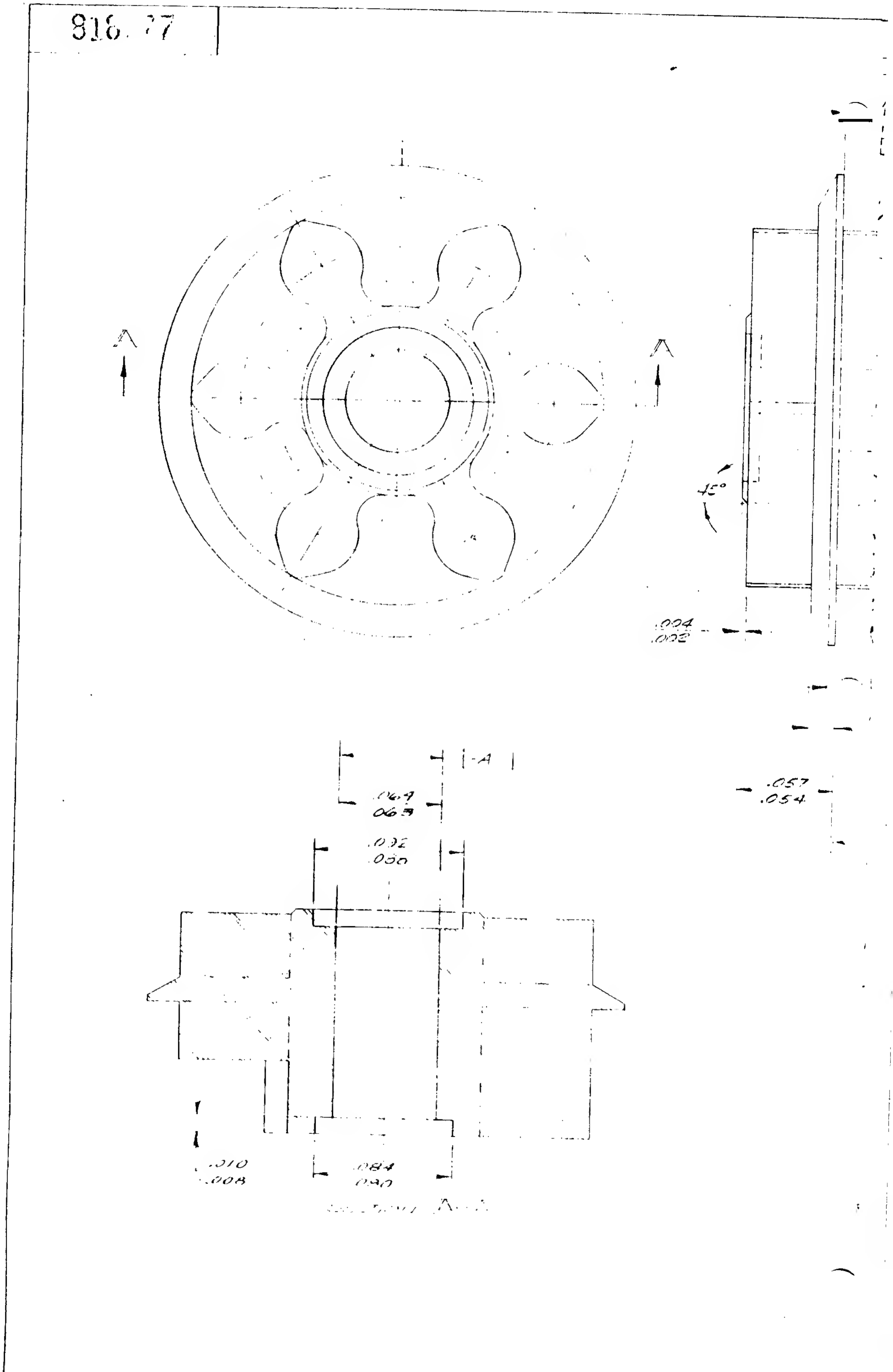
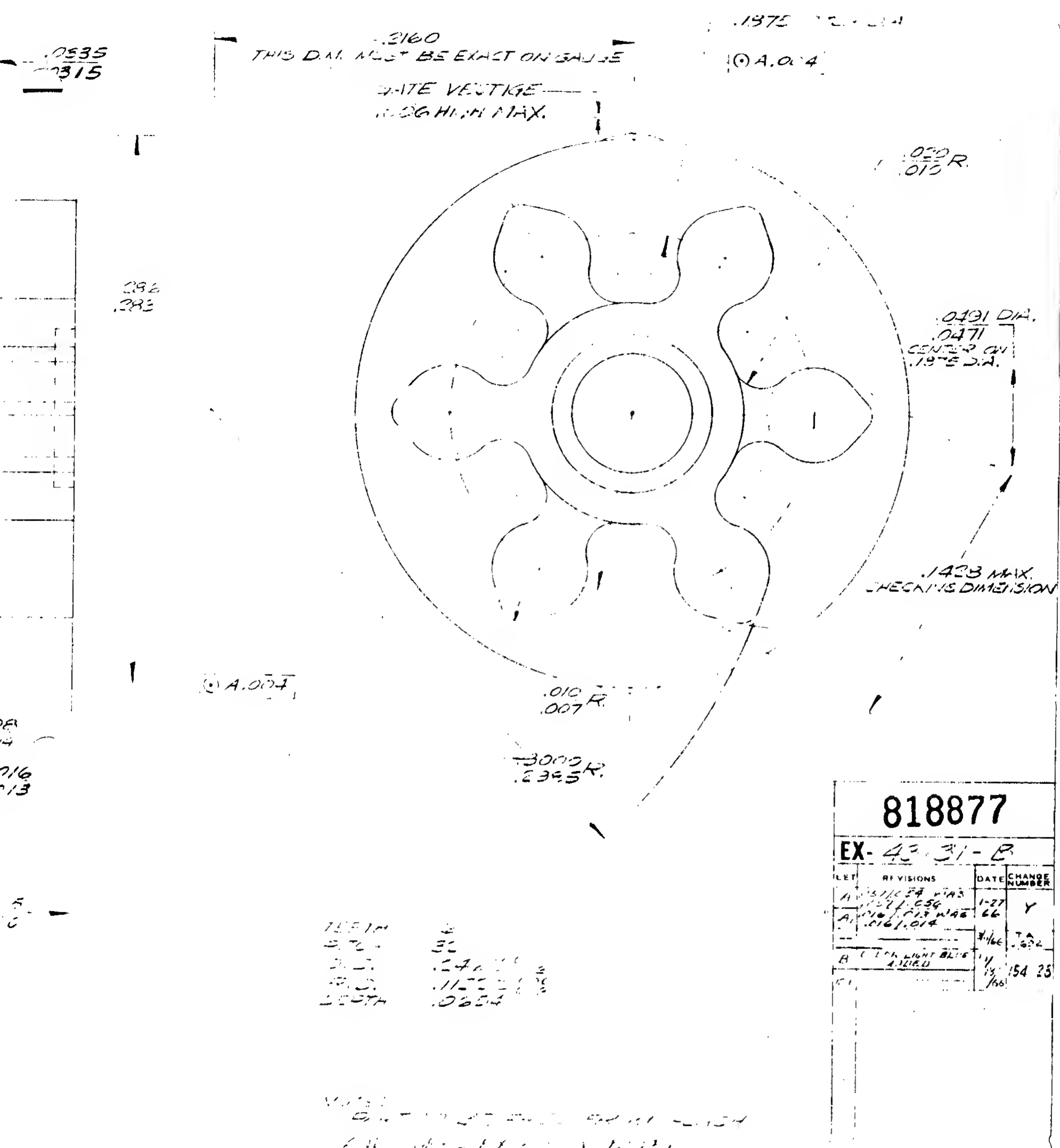


Exhibit B-2 PLASTIC PINION (redesigned)



818877

EX- 43-31-B

LET	REVISIONS	DATE	CHANGE NUMBER
A	.0535/.0315 WAS .0527/.0507; .016/.013 WAS .016/.014	1-27-66	Y
		3/14/66	T.A. 7632
B	COLOR LIGHT BLUE ADDED	5/13/66	154 25

FIRST USED ON

ALL DIMENSIONS GIVEN IN INCHES.
UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01
SURFACE FINISH PER S.W. STANDARDS.
SPECIFIED SHARP FILLETS OR CORNERS .005 MAX. RADIUS OR CHAMFER ALLOWED.
OTHERWISE .015 MAX. PERMISSIBLE.
STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

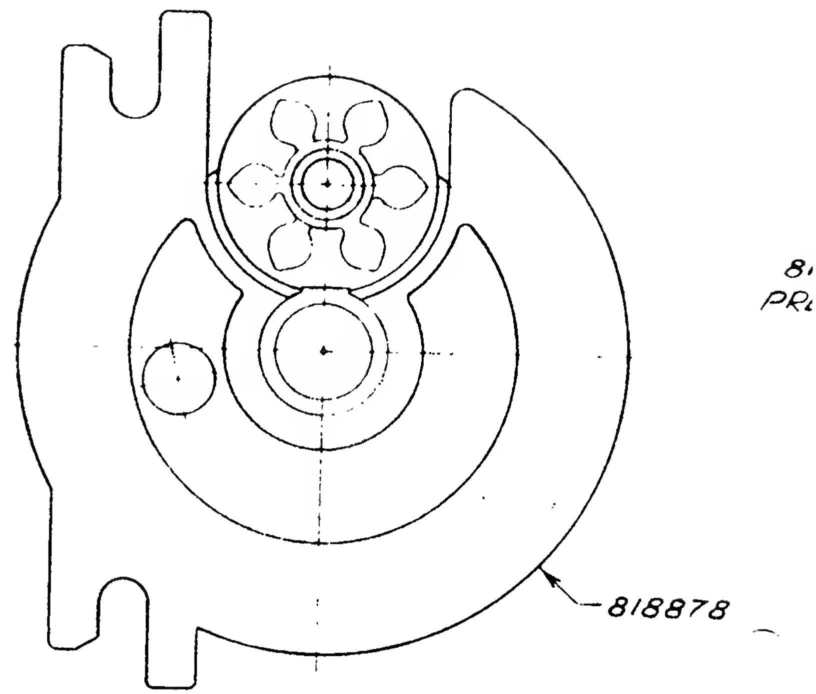
STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

DRAWN	DATE	NAME
S.R.	2-10-65	PINION
CHECKED	SCALE	FINISH
	20:1	
		HEAT TREATMENT

MATERIAL
POLYACETAL RESIN MOLDING COMPOUND (CELCON M-90) LIGHT BLUE

REQ.	NUMBER	NAME

818877



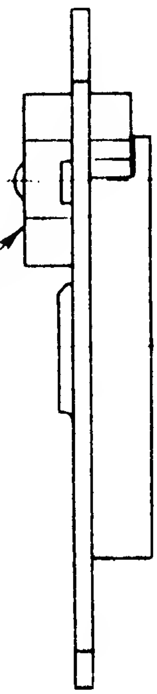
NOTE:
PINION MUST TURN FREELY
AFTER ASSEMBLING

Exhibit B-3 ALL PLASTIC PINION & BRACKET ASSEM

DRAWN	DATE	NAME		
B.R.	10-11-66	PINION & BRACKET ASSEM	1	8
CHECKED	SCALE	FINISH	MATERIAL	
	4 = 1		1	8
		HEAT TREATMENT		
			REQ.	

Form 12421 Rev. 12-62

ECL 71B



/ (intermediate design)

877	PINION
378	BRACKET, PINION
UMBER	NAME

N CONTAINED THEREIN WILL NOT BE REVEALED TO ANY
LL COPIES WILL BE RETURNED IMMEDIATELY ON DEMAND.

G819669

LET	REVISIONS	DATE	CHANGE NUMBER
—	————	10/13/66	15402B

FIRST USED ON G419213

ALL DIMENSIONS GIVEN IN INCHES. UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01. SURFACE FINISH PER S.W. STANDARDS. SPECIFIED SHARP FILLETS OR CORNERS .005 MAX. RADIUS OR CHAMFER ALLOWED. OTHERWISE .015 MAX. PERMISSIBLE. STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

G819669

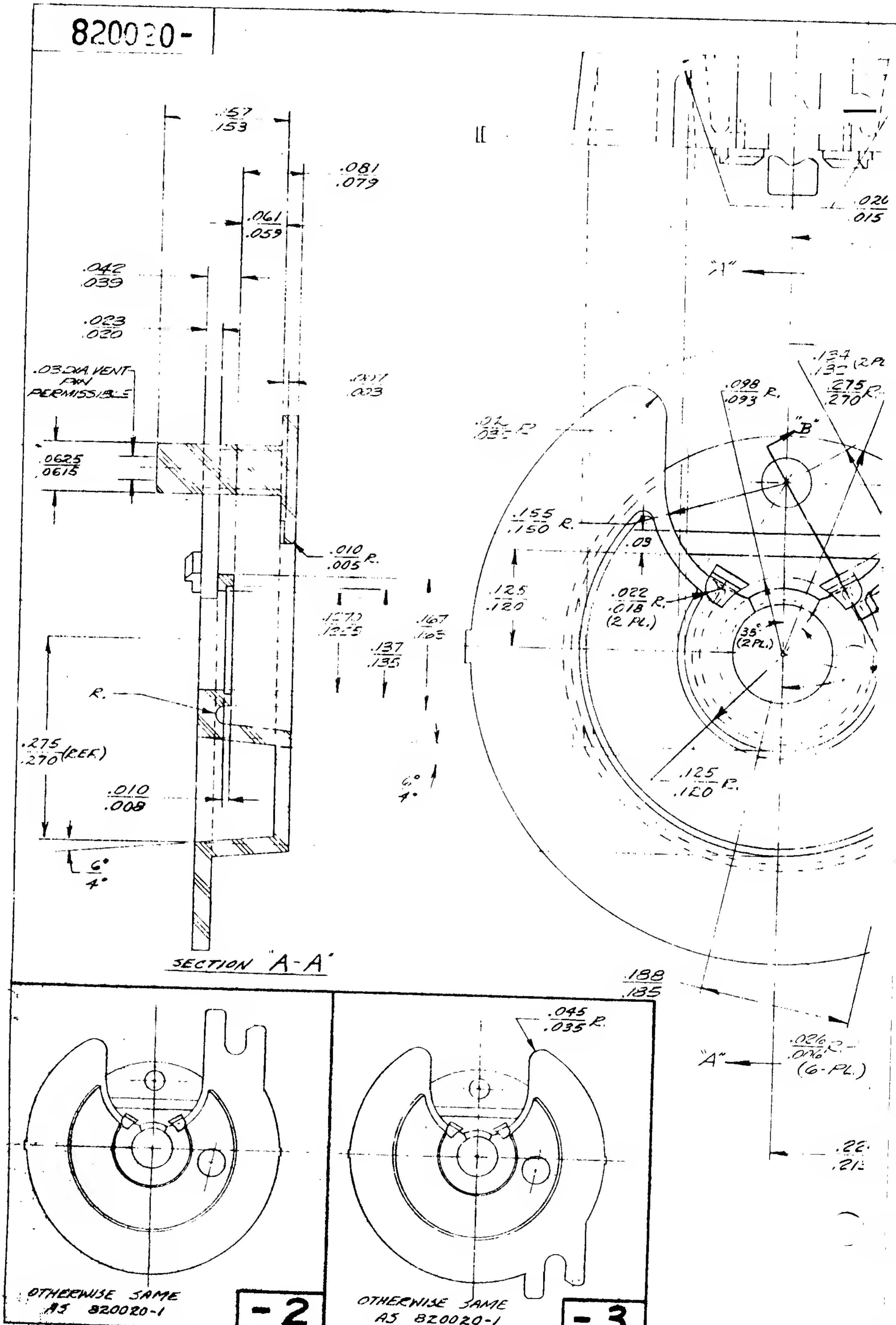
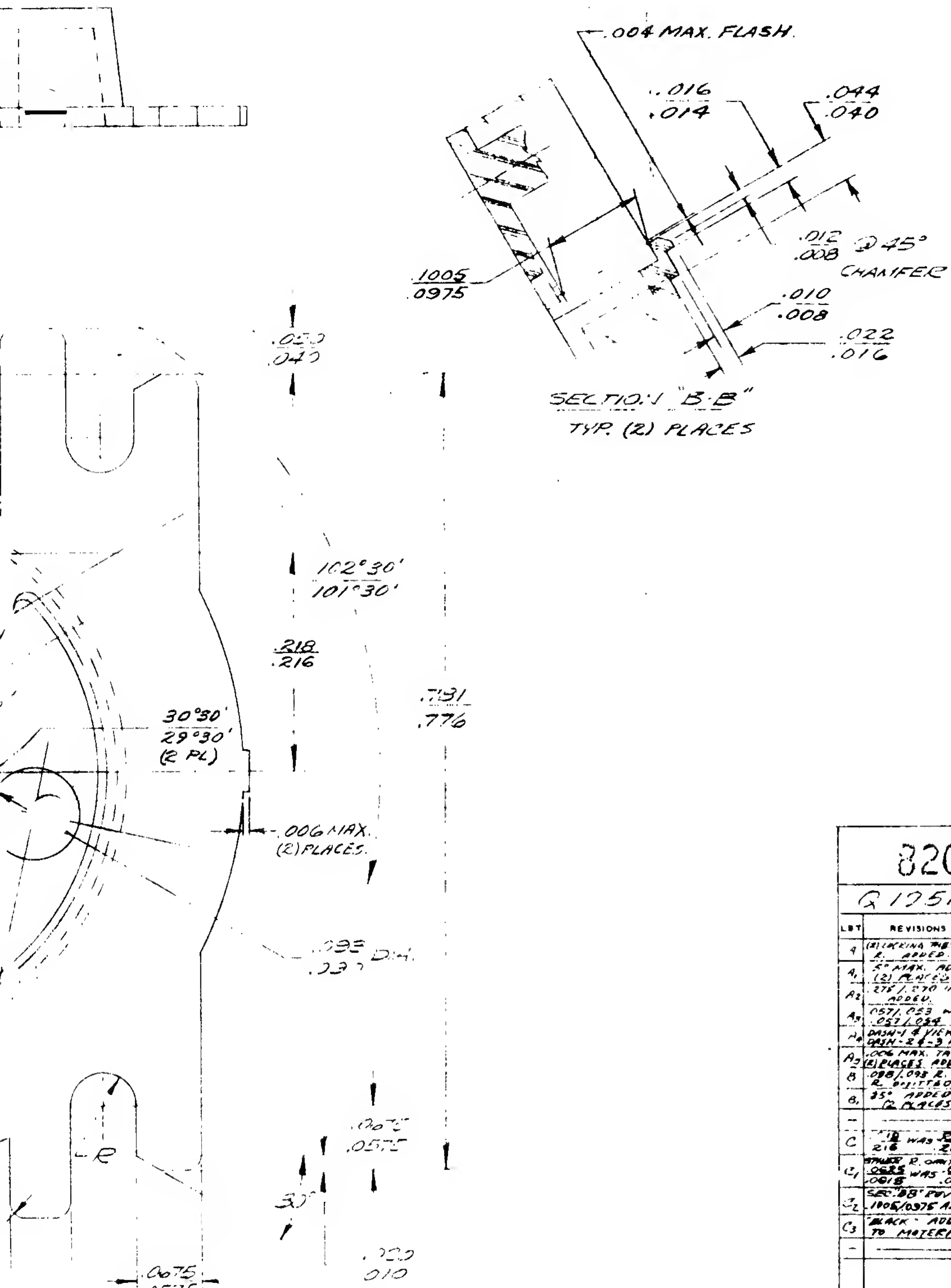


Exhibit B-4 FINAL DESIGN OF PLASTIC PINION BRACKET



NOTE:
NOMINAL WALL THICKNESS .027/.023 UNLESS OTHERWISE SPECIFIED.
ALL CORNERS AND FILLETS UP TO .005 R. EXCEPT AS NOTED.
MUST BE FREE FROM FLASH AND BURRS EXCEPT AS SHOWN.

SIMILAR TO 816878.

-1

820020-

Q 17512-A-

LET	REVISIONS	DATE	CHANGE NUMBER
A	(2) LOCKING TABS REV. R. ADDED.	1-3 67	P.S. T-52
A_1	.5° MAX. ADDED (2) PLACES.		
A_2	.275/.270 (REF.) ADDED.		
A_3	.057/.053 WAS .057/.054		
A_4	DASH-1 & VIEWS WITH DASH-2 & -3 ADDED.		
A_5	.006 MAX. TABS (2) PLACES ADDED.		
B	.098/.093 R. ADDED R. OMITTED	1-24 67	Y
B_1	35° ADDED (2) PLACES		
—	———	2-9 67	T.A. 51907
C	.218/.216 WAS .2165/.2145	6-6 67	154574
C_1	SPHERE R. OMITTED .0625/.0615 WAS .0620/.0606		
C_2	SEC. "BB" REVISED .1005/.0975 ADDED		
C_3	"BLACK" ADDED TO MATERIAL		
—	———		

FIRST USED ON

ALL DIMENSIONS GIVEN IN INCHES, UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01. SURFACE FINISH PER S.W. STANDARDS. SPECIFIED SHARP FILLETS OR CORNERS .005 MAX. RADIUS OR CHAMFER ALLOWED. OTHERWISE .015 MAX. PERMISSIBLE. STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

DRAWN	DATE	NAME	
S.R.	8-8-66	BRACKET, PINION	
CHECKED	SCALE	FINISH	MATERIAL
	10:1 4:1	NONE	POLY-ACETAL RESIN MOLDING COMPOUND (DELRIN) 911-01 (BLACK)
		HEAT TREATMENT	
		NONE	

REQ.	NUMBER	NAME

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

820020-

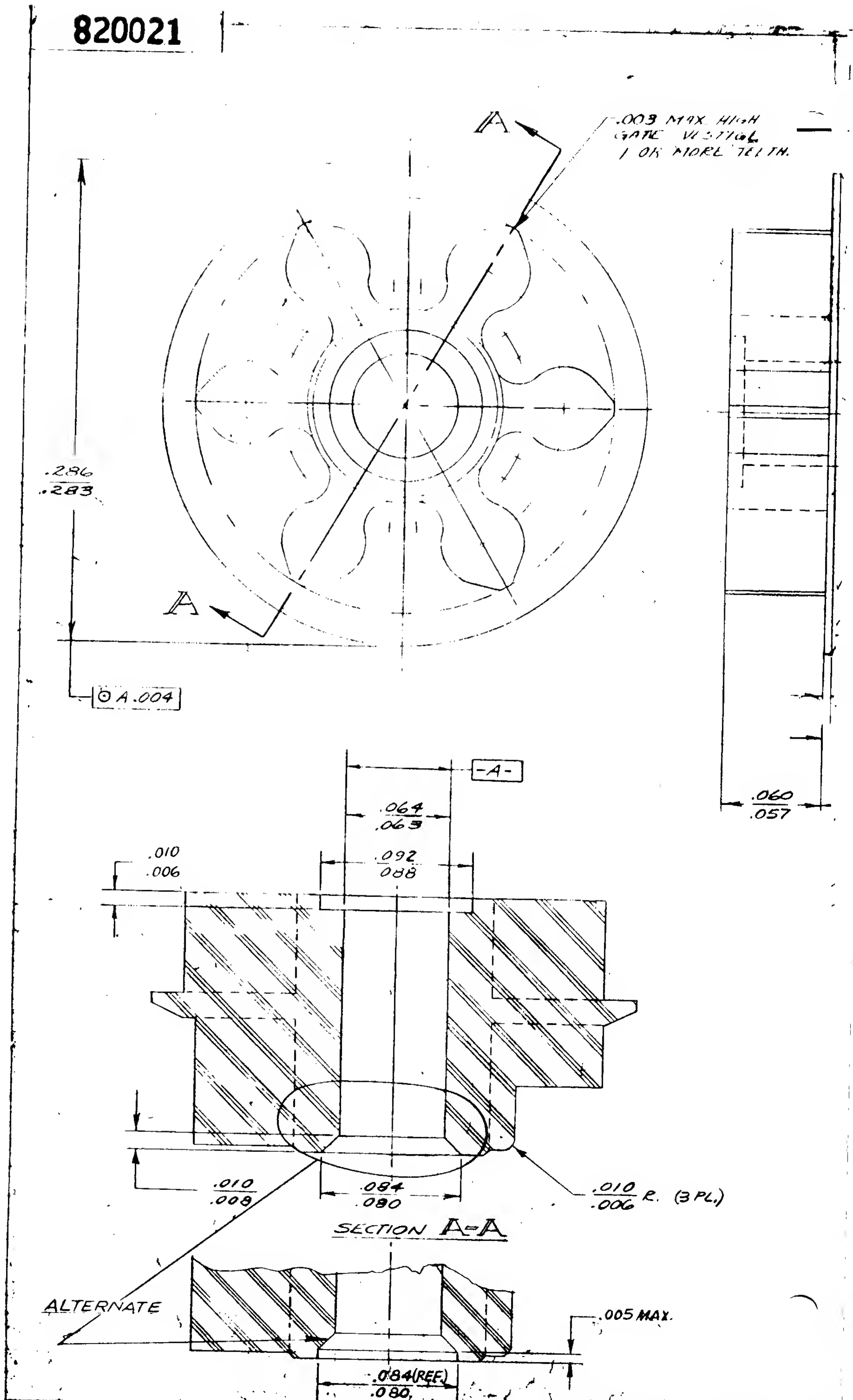
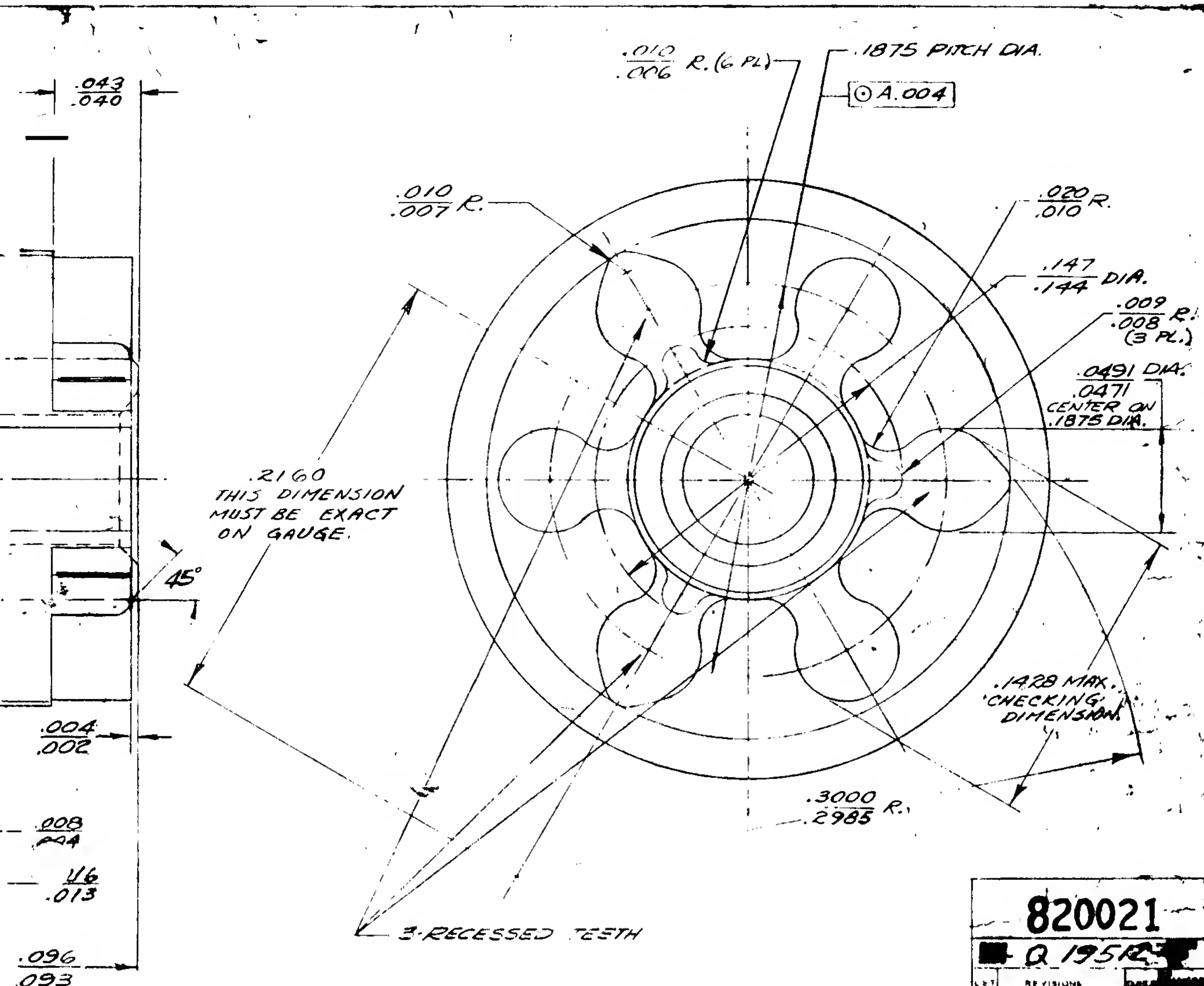


Exhibit B-5 FINAL DESIGN OF PLASTIC PINION



820021

Q 195R

LET	REVISIONS	DATE	APP.
A	.010/.006 R. (6) PLACES ADDED		
B		6-6-67	
C	CHAMFER (WAS 'AA') WAS C'BORE		
D	ALTERNATE VIEW OF SECTION A-A ADDED		155216
D1	.010/.006 ADDED	5-1-68	
D2	.006 MAX. GATE NOTE OMITTED		
D3	.008 MAX. GATE NOTE ADDED		

TEETH	6
PITCH	32
O.D.	.246/.243
R.D.	.1152/.1122
DEPTH	.0654

NOTE
PART TO BE FREE FROM FLASH AND BURRS EXCEPT AS NOTED.

ALL CORNERS AND FILLETS UP TO .005 R. EXCEPT AS NOTED.

SIMILAR TO 818877.

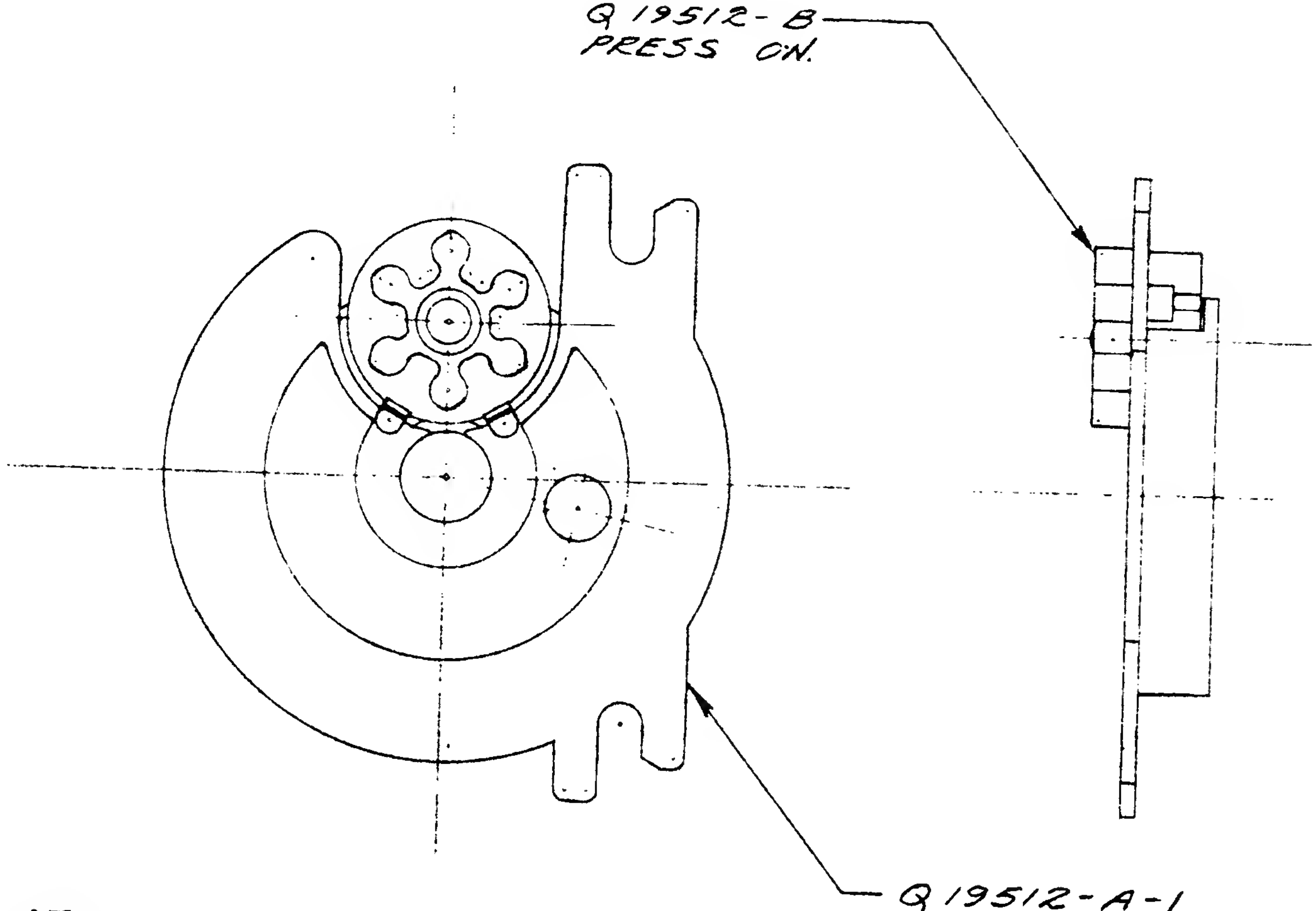
FIRST USED ON G 820445

ALL DIMENSIONS GIVEN IN INCHES UNLESS SPECIFIED, TWO PLACE DECIMALS ...

DRAWN	DATE	NAME	MATERIAL
S.P.		PINION	POLY-ACETAL RESIN MOLDING COMPOUND (DELRIN) 911-01 LIGHT BLUE
CHECKED	SCALE	FINISH	
	20-1		
		HEAT TREATMENT	

STEWART ... CORP.

820021



Q 19512-C

LET	REVISIONS	DATE	CHANGE NUMBER
A	Q19512-A-1 WAS Q19512-A	1-4 67	7-52

NOTE:
PINION MUST TURN FREELY
AFTER ASSEMBLING.

SIMILAR TO G819669. ~~X~~ 6

Exhibit B-6 FINAL DESIGN OF PINION & BRACKET ASSEMBLY

DRAWN	DATE	NAME
W. J. P.	11-7-66	PINION & BRACKET ASSEM.
CHECKED ✓	SCALE 4=1	

FINISH: —
MATERIAL: —
HEAT TREATMENT: —

REQ.	NUMBER	NAME
1	Q-19512-A-1	BRACKET, PINION
1	Q-19512-B	PINION

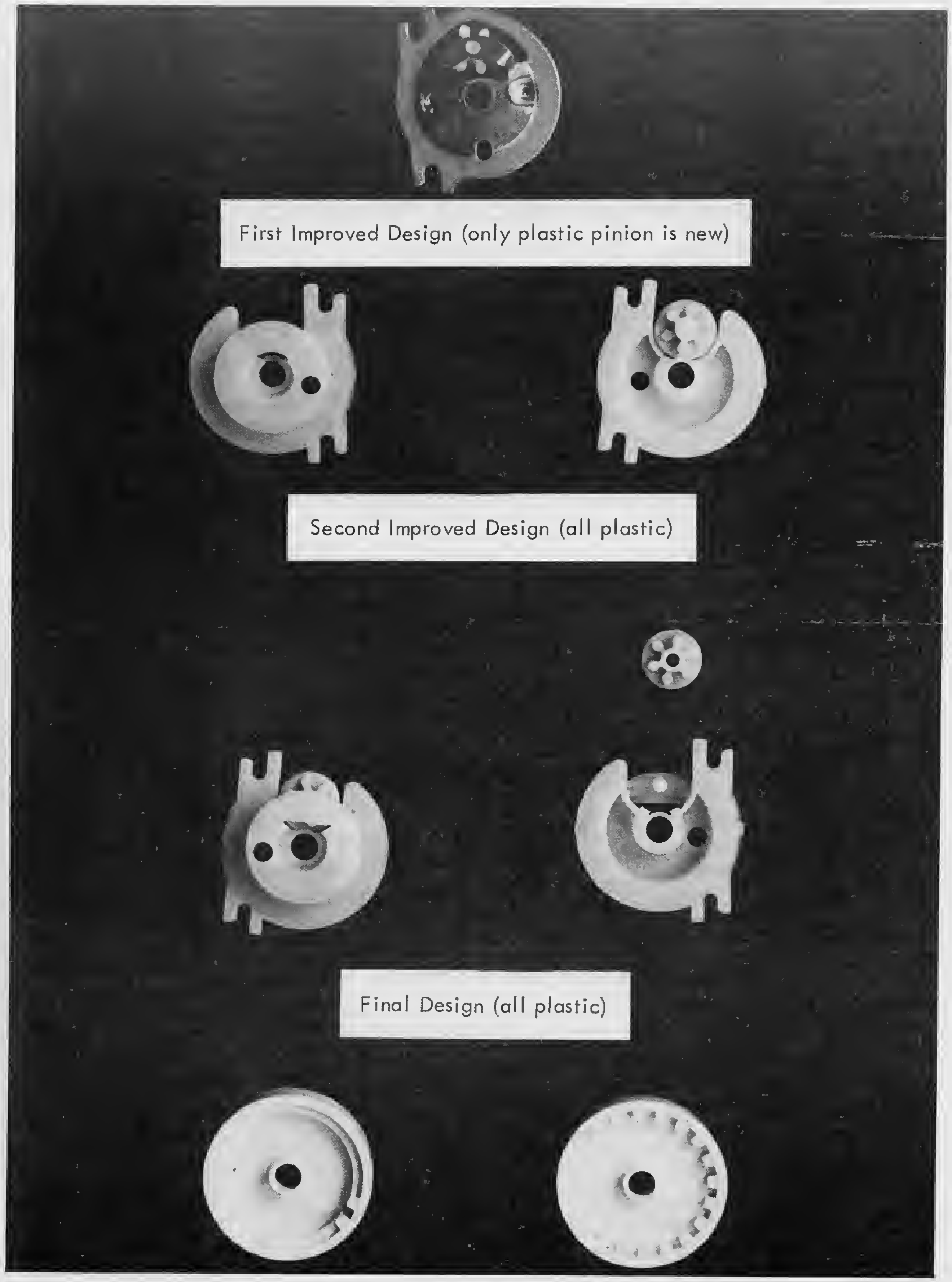
FIRST USED ON

ALL DIMENSIONS GIVEN IN INCHES. UNLESS SPECIFIED, TWO-PLACE DECIMALS ± .01. SURFACE FINISH PER S.W. STANDARDS. SPECIFIED SHARP FILLETS OR CORNERS .008 MAX. RADIUS OR CHAMFER ALLOWED. OTHERWISE .015 MAX. PERMISSIBLE. STOCK SIZES AND VENDORS TOLERANCES NOT INCLUDED.

STEWART-WARNER CORPORATION
CHICAGO, U.S.A.

ECL 71B

Form 12821 Rev. 12-62



Odometer Dial Wheel (left and right side views)

Exhibit B-7 PINION & BRACKET ASSEMBLY THROUGH VARIOUS DESIGN STAGES

INSTRUCTOR'S NOTE

Assignment

This case comes in two chapters, the first of which should be worked before reading the second. The two chapters can either be given to students at the same time with this admonition or can be handed out sequentially.

An appropriate assignment for the first chapter can be simply: "Analyze the case, define the engineering task to be done and proceed with the job from the end of the case as best you can with the information available."

In class, then, students can be asked to present their analyses either in written reports or by explaining their results orally, preferably at the blackboard.

Suggested Questions for Discussion

1. What specs would you suggest for this product?
2. How does the present odometer work? Can you sketch it and describe the action?
3. What seems to be going wrong? Can you sketch what happens?
4. What solutions did you think of? What solution ideas did you reject?
5. What constraints did you assume in choosing a solution?
6. What other information did you need or would you like to have in this case?

Possible Answers to Discussion Questions

1. Specifications - From the case inferences can be drawn as to (1) the need to read out up to 99,999.9 miles, (2) the need to fit within the existing size envelope, and (3) the need to be gear driven at the present rate. Further possible inferences are (4) cost should be 30 - 40 cents in large quantities, and reliability needs to be greater than 99.9%.

2. How does the present odometer work? This is described in words and pictures in the case and is not easy to comprehend immediately. If a student can describe and sketch it in his own way it will be clear that he has applied thought to

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Prepared by Karl Vesper, Associate Professor, Mechanical Engineering Department, University of Washington, December 1970. Published in the Engineering Case Library, Stanford University.

understanding the case. He may argue that real life would give him a physical example to study, which is true. The mechanism, however, effectively has to be closed up in order to work, so even with the real device operation is not fully apparent. Moreover, real life often does require designers to visualize the action of things that do not (yet) physically exist. So the mental exercise is not irrelevant.

3. What is going wrong? There appears to be three main problems, as follows:

a. Variations in end play of (1) the between-segments pinion, and (2) the whole odometer.
b. Occasional improper alignment of the pinion bearings in the pinion bracket.
c. Burrs.

4. What are possible solutions?

a. Redesign the bracket welder. (Data insufficient to explore this)
b. Change assembly jigs or deburring processes. (Not described in case)
c. Test each odometer 100 miles. (Most failures occur there)
d. Change to electronic rather than mechanical odometer. (likely expensive)
e. Mount pinion on a shaft about which it turns and which spaces the bracket halves.
f. Dimple the bracket pieces to help align them for welding.
g. Drill or punch bracket bearing holes after welding.
h. Form bracket by curling it around in one piece, rather than welding separate pieces, then "popping in" the pinion.
i. One piece bracket with cantilever pin for gear mount.
j. Cast the bracket in one piece instead of stamping.
k. Check whether heat treatment or other processing following welding causes problems.
l. Make gear in two pieces which press together through a hole in the bracket.
m. Impose tighter (1) tolerances and/or (2) quality control.
n. Align the two bracket halves with pins during assembly.
o. Let pinion bearing be between the two sides of the gear (like a yo-yo) and straddle a one piece bracket.

The tendency for students will be to consider only one or two of the above alternatives, and the extent to which they think of more can be a measure of their performance.

5. Constraints in choosing a solution. These were suggested in answer to question "1" above. Tooling or changeover cost is probably not too important, but the cost per unit is vitally so, as is reliability.